March 2003
Volume 21, Number 2

Reduction of destructive tests for PVC seams

PVC geomembrane air-channel testing may reduce field destructive seam testing.

By Richard W. Thomas and Timothy D. Stark

One of the current research topics being pursued by the PVC Geomembrane Institute (PGI) is the thermal welding and subsequent air channel testing of PVC geomembrane seams, which is the focus of this article. Other active research projects include the long-term performance of PVC geomembranes using field case histories, shear behavior of PVC geomembrane interfaces, puncture characteristics of PVC geomembranes, and the chemical resistance of PVC geomembranes. These projects will be discussed in future articles.

Thermal welding of polyvinyl chloride (PVC) geomembranes has proven to be an efficient and cost-effective method of field seaming since 1991 and has been used for factory fabrication since 1982. PVC geomembranes possess excellent thermal welding characteristics such as a wide thermal seaming range, lack of residual stresses or stress cracking, and no required surface preparation, such as 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.

***Photo 1a**. Dual-track welding PVC geomembranes at TRI/Environmental in Austin, Texas.*

The focus of this study is to utilize these welding characteristics to develop a procedure for air channel testing of dual-track thermal seams and recommend that destructive testing of PVC geomembranes be reduced and possibly discontinued for PVC geomembranes. This is possible because of the development of a relationship between thermally welded seam burst strength and the seam peel strength (ASTM D 6392) for a given sheet temperature. To develop this relationship, test welds were created using hot air and wedge welders at two different geomembrane temperatures, two different geomembrane thicknesses, three welding speeds, and three welding temperatures.

The thermally welded seams used in this study were created in a single day in Austin, Texas at TRI/Environmental on an asphalt subgrade. Installation crews from two companies (Environmental Protection Inc. and Colorado Lining International), one using a hot air welder (see **Photo 1a and 1b**) and the other using a hot wedge welder, respectively, created the seventy-two 9.2-m (30-ft.)-long thermal seams used in this study. The hot air machine is a Leister Twinnie Model CH6056. The hot wedge machine is a Mini-Wedge made by Plastic Welding Technologies (formerly Columbine Inc.). The 0.75 to 1.00 mm (30 to 40 mil) PVC geomembrane used in the thermal seam testing was provided by Canadian General-Tower Ltd. of Cambridge, Ontario, Canada.

Photo 1b. *Hot-wedge welding.*

A seam burst test was created to develop the relationship between thermally welded seam burst strength and the seam peel strength. This relationship allows the burst test to be used in the field to test the entire length of a PVC seam for the specified peel strength instead of using destructive peel tests over a limited portion of the seam. It is anticipated that the use of the burst test will lead to a reduction in the destructive testing required during field installations and more reliable field seams because the entire seam is tested.

An important difference between air-channel testing of PVC geomembranes seams versus other geomembranes, e.g., high-density polyethylene (HDPE), is the flexible nature of a PVC geomembrane, which allows the field technician to see the air channel inflate as the air pressure migrates down the seam. The inflated air channel somewhat resembles an inflated inner tube, and this distinctive behavior has been referred to as “inner tubing” or “ballooning” of PVC seams. If a weak spot is encountered and leaks, the air pressure may not fully inflate the seam at this weak spot. **Photo 2** presents a 0.75 mm (30 mil) geomembrane with an inflated air channel in the field. It can be seen that the air channel is inflated (inner tubing), readily visible, and maintaining the air pressure.

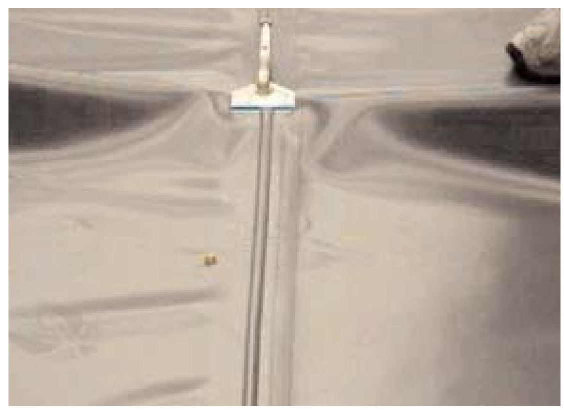

Photo 2*. Inflated air channel in 0.75 mm (30 mil) geomembrane in the field.*

The seams in this study were evaluated by the standard peel test at 20 in./min at 73°F (ASTM D 6392, 1999) and by the seam burst test (**Photo 3**) developed during this project. The burst test was performed by sealing off one end of a seam length and pressurizing the other end with compressed air. The seam length tested in the burst test was 2 m (6 ft.). The basic test procedure involved selecting a starting air pressure, holding that air pressure constant for 30 seconds, then increasing the air pressure 5 psi at a time, and holding the new air pressure another 30 seconds. This was repeated for each 34.4 kPa (5 psi) air pressure increment. The 34.4 kPa air pressure increment was achieved in a 5-second time period. This procedure of increasing the air channel pressure, holding the air pressure, and then increasing the air pressure by 34.4 kPa continued until the seam “burst.” Most of the burst failures involved the peel mode, which occurred during the 30-second holding period. However, some seams burst during the 34.4 kPa air pressure increase step.

The seam peel strength was compared to the burst pressure in this study because pressurizing the air channel results in the seam being challenged more in a peel mode than a shear mode. Therefore the seam peel strength, and not the seam shear strength, was used for comparative purposes. It is important to note that the burst test fails the seam from the inside towards the outside of the seam, whereas the peel test fails the seam from the outside towards the inside of the seam. The impact of this difference, if any, is a subject of the ongoing research, but it does not impact the results herein because PVC seam requirements are specified in terms of peel strength, and the burst pressure is simply being correlated to this specified parameter. The required value for the peel strength of both 0.75- and 1.00-mm (30- and 40-mil)-thick PVC seams, according to the PGI material specification (PGI 1997), is 2.6 N/mm (15 ppi).

Photo 3. *Seam burst test being performed.*

The main contribution of the air-channel testing research is the development of a relationship between peel strength at room temperature (22.8°C; 73°F) and the burst pressure at sheet temperatures ranging from 22.8 to 46.7°C (73 to 116°F) as shown in **Figure 1**. This relationship was developed from the test results obtained during the research program and from Arrhenius modeling that allows the data to be extended to sheet temperatures below 22.8°C and above 46.7°C. This relationship allows field personnel to perform seam QA/QC operations without conducting destructive tests because the seam peel strength can be measured indirectly by applying air pressure to the air channel in a dual track weld. This field air channel test can be used instead of destructive seam testing, which has the advantages of not cutting holes in the geomembrane, no geomembrane surface preparation such as grinding, and no patching the resulting geomembrane.

The main 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. This procedure, coupled with the flexibility of PVC geomembranes, which allows the air channel to expand (inner tube) so field personnel can visually inspect the seam as the air pressure migrates along the channel, and the fact that the presence of any defect may not allow the air channel to fully expand or inflate in the vicinity of the defect, results in a excellent means for ensuring the integrity of field thermal seams in PVC geomembranes.

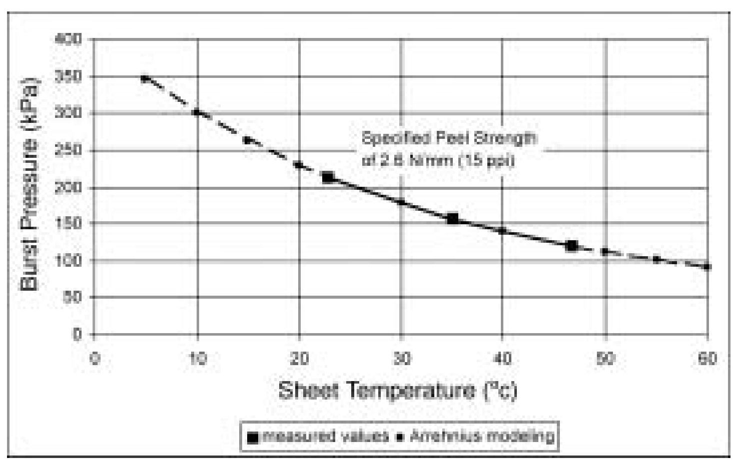

Figure 1. *Burst pressure required to ensure a specified peel strength of 2.6 N/mm (15 ppi) at various sheet temperatures.*

Some of the results from the larger study on the thermal welding of PVC geomembranes include understanding the effects of welding temperature, welding speed, and sheet temperature on seam performance. These variables were evaluated for two geomembrane thicknesses and two types of welder, i.e., hot air and wedge welders, using the results of seam peel tests (ASTM D 6392) and the new burst test. These results are the subject of a subsequent technical paper (Thomas and Stark 2003). The seam test results show that welding speed has a greater impact on the measured peel strength than welding temperature. Therefore, welding personnel can increase the seam peel strength for a given sheet temperature and welding temperature simply by reducing the speed of the welder. A welding speed in the range of 0.9 to 2.1 m/min provides the best seams under the widest range of sheet temperature, geomembrane thickness, and welding temperature. Welding speeds as high as 3.1 m/min can produce good seams, especially if the sheet temperature is high via sunshine and/or the welding temperature is high.

The seam test results also show that a welding temperature of 315.6°C (600°F) is too low and a welding temperature of 482.2°C (900°F) is too high for this 0.75-mm (30-mil)-thick PVC geomembrane. Therefore, an optimal welding temperature to initiate welding is 398.9°C (750°F) for this 0.75 mm (30 mil) PVC geomembrane. The test results also suggest that an optimal welding temperature might range from 454.4 to 468.3°C (850 to 875°F) for a welding speed of 3.1 m/min for 1.00 mm (40 mil) thick seams. GFR

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R. W. Thomas is the technical director for TRI/Environmental Inc., Austin, Texas.

Timothy D. Stark is a professor of Civil and Environmental Engineering at University of Illinois, Urbana, Ill.