# When field seam test results sail, yet laboratory test results pass: A practical approach to understanding why

*Cristopher* Eichelberger[1], *Ryan* Kamp[2], and *George* Koerner[3*]

[1]AGRU America
[2]Chesapeake Containment System, Inc.
[3]Geosynthetic Institute (GSI)

**Abstract.** A standard quality control (QC) and quality assurance (QA) plan during installation of an unreinforced polyethylene geomembrane often requires destructive testing of the production welded seams at regular intervals. This testing is different from "trial weld testing." Prior to welding of the seams, within the project footprint, a "trial weld" is fabricated on site as a proficiency test. The procedure utilizes project specific geomembrane material, environmental conditions, welding technician and equipment intended to perform the seaming of geomembrane installed as part of the containment system. There are cases where on-site trial welds become difficult to pass, even when experienced crews, quality equipment and materials are present. The difficulty can lead to a scenario where trial welds fail and destructive seam tests pass when sent to a 3rd party lab for testing, (this is a nightmare for geomembrane installers). Variables are numerous and often difficult to identify between these two different testing scenarios. However, this paper will show results and insightful data that will give rationale for the discrepancy.

## 1 Introduction

Prior to welding a seam within the actual project area to be lined, a technician will set-up a specifically identified wedge or extrusion welder to perform a trial weld on a geomembrane delivered to the project site for installation. The machine identification and welding technician are identified and correlated to each trial seam. The completed trial seam is then tested via ASTM D6392 peel and shear tests using an on-site tensiometer and the results are compared to project specifications contained within the CQA plan (i.e., GRI GM19 seam specifications).

Once it is demonstrated that the welding technician and associated welding equipment can weld a seam of the actual geomembrane being installed that day for the project, they are cleared for production welding. The settings of the machine will stay consistent for the next four to five hours of welding until changes are required. These changes will necessitate a repeat of the trial seam procedure. If the trial weld does not pass, the technician will make

*Corresponding author: gsigeokoerner@gmail.com

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adjustments to the welding equipment (i.e., temperature setting, speed control, pressure of nip rollers, etc.) and produce another trial seam for evaluation. The trial weld procedure is routinely carried out over the course of the day for both extrusion and fusion seaming.

It should be clearly stated that there are several other reasons why trial weld fails and yet lab test passes. Four reasons beyond this paper are summarized below;

1. Temperature: Tensile strength of HDPE geomembranes is extremely sensitive to temperature. Xue, Q. et. al. (2013) suggests that there can be a 20 % range from extreme ambient to 21+/- 2 °C. It is generally understood that the higher the temperature the lower the strength. There obviously is a major effect on both shear and peel strengths when comparing field testing on a hot summer day compared to lab testing of conditioned specimens which are tested within a climate-controlled environment per ASTM D35 guidelines.

2. HDPE with different yield strengths: Not all HDPE geomembranes have the same yield strength. For starters, we actually use MDPE resin to make HDPE geomembranes. It is only when we combine the MDPE resin with the masterbatch (which contains CB at a density of 1,3 g/cc) that it eclipses the 0.94 g/cc ASTM threshold for HDPE. Furthermore, most manufacturers are now blending resins to ward off the possible issues with stress cracking. As such, there is a greater range of yield strengths available under the GRI GM13 umbrella of acceptable materials. Khan and Jeon (2012) suggest that there can be a 15 % range in yield strength within the commercially available resins for geomembrane production.

3. Difference between cast and blown film resins: The most significant difference between geomembrane formulations for cast and blown film is melt flow index (MFI). The resin for a cast geomembrane line has a lower MFI than a blown film line. Hence, the geomembrane produced on the blown film line is stiffer and has a higher yield strength than material produced on a cast (wide mouth extruder) geomembrane line. Struve and Koerner (2005) suggest that there can be a 7 % range in yield strength within the commercially available resins for geomembrane production between cast and blown film resins.

4. Thickness: As discussed by Koerner (2023), weld edge thickness in linearly proportional to strength. If the weld edge is thinner than the parent material specified, there will be a potential for substantive lower seam strengths.

It should be clearly stated that although these factors affecting strength may be significant, they will not be factored into this investigation nor will their synergic effect be superimposed on the rheology/curing discussion to follow. It is freely admitted that this phenomenon is complex with many variables. Therefore, this experiment has its limitations.

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## 2 HDPE seam curing and rheology

Extrusion and fusion welding are the two most common methods of producing seams in HDPE geomembrane fabrication. Unfortunately, heat welded seams do not reach full strength until they are fully cooled and welded seams require a period of time for curing in order to reach full strength.

**Fig. 1.** Photographs of Fusion or wedge welding/seaming of HDPE geomembrane

Currently, there is an increasing requirement for trial weld testing of geomembrane seams at the earliest possible time. Hence, there is little curing of seams during this time crunch. Unfortunately, the age or curing of the sample will affect the test results and should affect the engineer's interpretation of these results.

**Fig. 2.** Photographs of the extrusion welding/seaming of HDPE geomembrane process

To evaluate the effect of curing time on weld strength, GSI began a study of the curing HDPE field seams. Four 50-foot-long seams of 60 mil HDPE were fabricated using typical fusion and extrusion fabrication techniques in the field as shown in Figures 1 and 2. The seams were then cut into 24" long test sample blanks. These samples were then tested at the following intervals: 15 minutes, 1, 2, 3, 5, 8, 24, and 72 hours. The results from these tests were then plotted on four graphs:

1. extrusion peel versus cure time "age"
2. extrusion shear vs. age
3. fusion peel vs age
4. fusion shear vs. age

These graphs were well behaved with a correlation coefficient of 0.95 and 0.92 respectively for shear vs. age, and 0.90 and 0.88 for the peel vs. age. Please note that the fusion peel tests had six sets of data and compare to three sets for the rest of the welds because the seam was dual hot wedge weld with both and "A" and "B" track.

While the applicability of these results is limited to the materials and methods used, they do show that HDPE seams will increase in peel strength over time relatively quickly (one to two hours). ASTM D6393 "Standard Test Method for Determining the integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods," requires 40 hours of conditioning time in the laboratory prior to testing seams for shear and peel. As can be seen from the data presented here, this should be sufficient time for the seam to reach its ultimate strength.

While it is sometimes necessary to test the seams when fairly new (10-20 minutes after welding), the results of these tests should not be taken as representative of the ultimate seam strength of the materials. Caution should be used in evaluating the strength data only. The locus of break code and the ductility of the seam are critical.

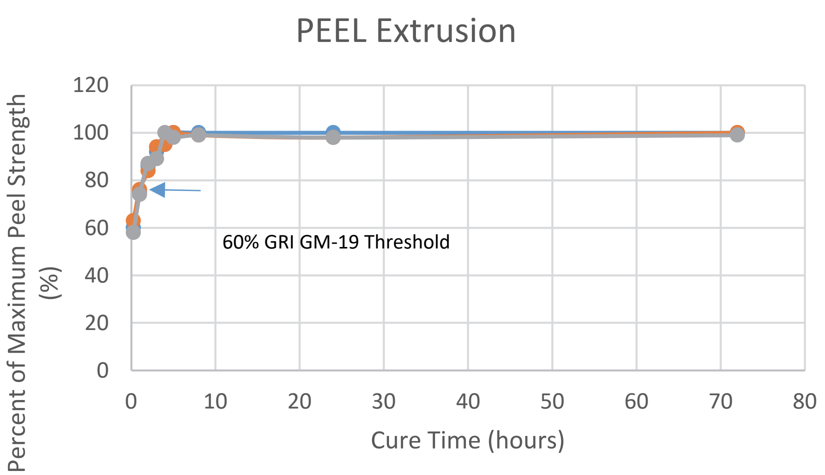


**Fig. 3.** Shows three sets of HDPE curves for the peel strength versus cure time for an extrusion weld. Please note that the peel strength has been normalized as a percentage of the average maximum peel strength of the data set of three.

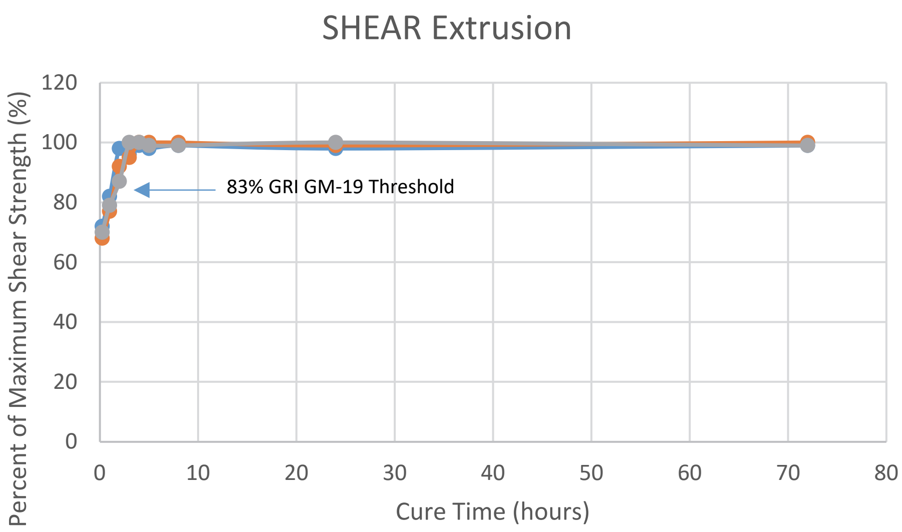


**Fig. 4.** Shows three sets of HDPE curves for the shear strength versus cure time for an extrusion weld. Please note that the shear strength has been normalized as a percentage of the average maximum shear strength of the data set of three.

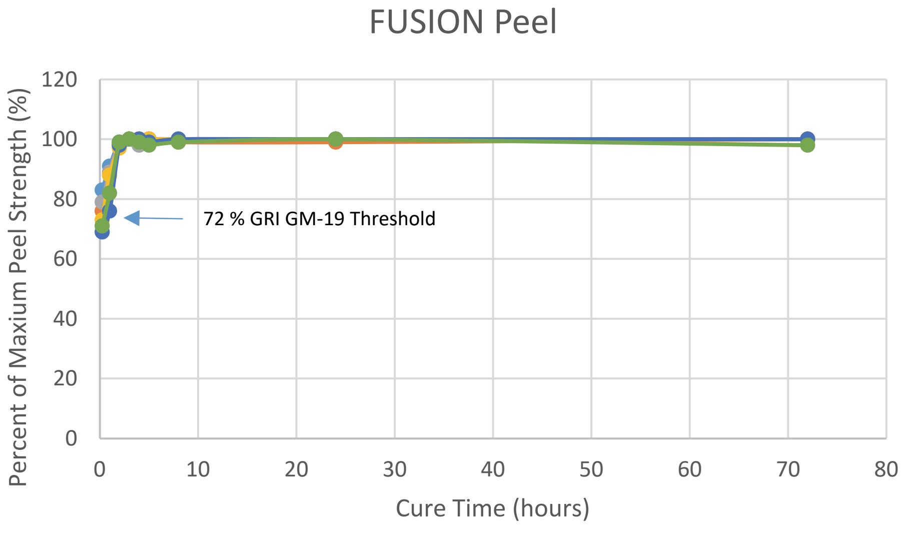


**Fig. 5.** Shows six sets of HDPE curves for the peel strength versus cure time for a fusion weld. Please note that the peel strength has been normalized as a percentage of the average maximum peel strength of the data set of six.

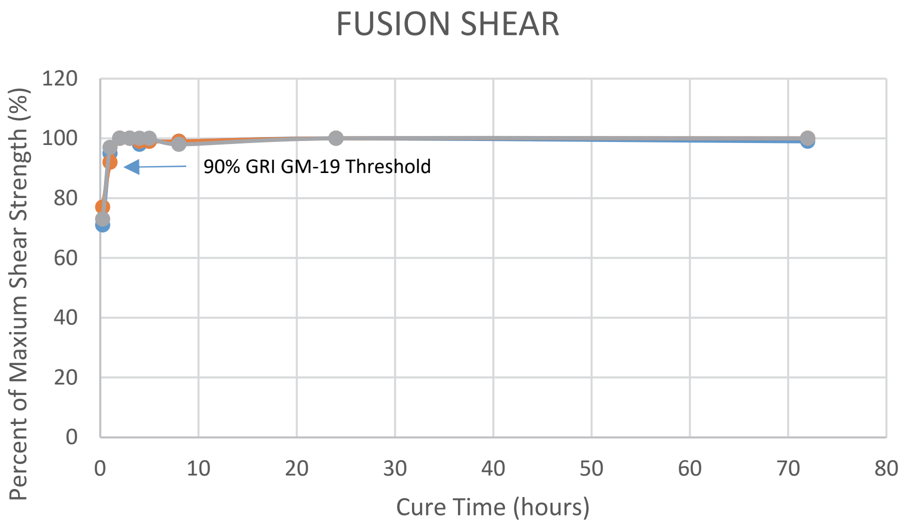


**Fig. 6.** Shows three sets of HDPE curves for the shear strength versus cure time for a fusion weld. Please note that the shear strength has been normalized as a percentage of the average maximum shear strength of the data set of three.

## 3 Summary and conclusion

From field experiments of extrusion and fusion HDPE seaming, it has been shown that the cure time is not short. It is hours rather than minutes. As a result, installers are left guessing if their trial welds are good indicators of seam quality. This puts the CQA personnel in a quandary regarding when to release the welding technician and equipment into production seaming.

It has been shown that fusion seaming reached 100% of the maximum seam strength for peel and shear strength much sooner than extrusion. We have seen rapid cooling techniques used like ice bucket dunk or a cold wet rag, to arrive at higher weld strengths quicker. However, these techniques are not standardized and the CQA industry is skeptical of the results of these quick quench tests.

As mentioned in the introduction, this issue is complex and merely one reason why field seam test results fail, yet laboratory destructive test results pass. HDPE seams cure relatively quickly (in an hour or two) however when pressed to complete the job, this is a long wait for and installer and CQA technician.

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