Cutting holes for testing vs. testing for holes

When it comes to geomembrane quality assurance, are destructive testing practices as effective as basic leak detection technologies?

The function of a geomembrane liner is to prevent liquid flow to the environment. CQA measures should be judged on how effective they are in meeting this requirement. This article critically examines the industry's current means of providing confidence that final installed geomembranes do not leak.

Destructive seam tests: CQA cornerstone or millstone?

In the early days of geomembrane installation, research and the resulting technical guidance put a heavy emphasis on how to create and check for good seams. The underlying assumption was that seams were the "weak link" because they were often created under less-than-optimal field conditions by technicians subject to human error. Indeed, the landmark textbook on designing with geosynthetics (Koerner 1994) states in a discussion of the most important aspects of geomembrane construction, "Seams should be at the top of everyone's list." From that perspective, the industry responded by instituting a plethora of required CQA documentation in the form of seaming logs, panel logs, temperature measurements, start-up procedures, non-destructive testing procedures, and destructive testing procedures. Much of this was promulgated by the U.S. EPA (1991, 1993).

The seaming of polyethylene geomembranes—by far the most common type in the waste containment industry—requires trained personnel and special equipment. These specialized installation requirements tend to create a mystery surrounding the welds, which then seems to compel organizations to do even more testing.

The rationale and justification for requiring even more scrutiny of field seams was fueled by the phenomenon of stress cracking in HDPE geomembranes, where it was noted that most of the stress-cracking problems were immediately adjacent to and in field seams. Since polyethylene in the early days was already prone to stress cracking wherever stress concentrations occurred, field seaming activities greatly exacerbated the issue by both introducing stress concentrations and degrading the polymer with heat in the vicinity of the seams. Dramatic field failures, some continuing even to this day from older installations, led to more and more recommendations regarding verification and field testing of seams in an effort to minimize the potential for stress cracking. In fact, the greatest strides in the stress cracking arena came not so much from improved seaming methods and quality assurance, but

Photo courtesy Thiel Engineering

Photo 1. Cutting holes in geomembrane for testing.

Photo Courtesy Leak Location Services, Inc.

Photo 2. Testing geomembrane for holes and cuts.

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rather from the polyethylene resin manufacturers. The fact is, the stress-cracking problem was aggressively addressed and, in the authors' opinion, largely solved, at least with the high quality resins being used in North America. Any specification following GRI GM-13 should provide a satisfactory material resistant to stress cracking. Of course, good seaming practice is still important, especially for exposed conditions. Nonetheless, the intense scrutiny over field seaming procedures, voluminous record keeping, and intensive destructive testing begins to feel like overkill.

The CQA battle

Monitoring a geomembrane installation is like engaging in battle. The enemy is defined as that which would destroy the integrity of the geomembrane.

There are many fronts to cover, beginning with conformance testing of the material and ensuring that roll numbers in the field correspond to what was to have been shipped and tested. During installation there is the customary subgrade sign-off form; then the real sorties begin. Multiple seaming personnel, matched up to specific welding machines, must all receive start-up tests, usually given at least twice per day. There must be documentation of the geomembrane temperature (usually taken precisely 6 in. above the liner), watchfulness over the pressure testing (Is the correct dwell time used? Are the gauges working? Do the needles hold the pressure?), and vacuum box testing of the extrusion welded patches. Meanwhile, the seam lengths and seam numbers must be cross correlated with panel numbers and seams. Finally, the CQA monitor, possibly armed with a knife, selects where to cut out 5-ft.-long sections of seam that are, by industry statistics, perfectly good seams approximately 97% of the time. Depending on the rules of engagement established by the jurisdictional state or federal environmental security council, an elaborate set of formulae dictates strength, peel, failure mode, and pass/fail criteria which often must be performed off-site at a laboratory or, occasionally, on-site in an air-conditioned trailer.

Finally, the engagement finishes. The seams are done, all the necessary repairs have been made, and the area is cleared to be overlain with a drainage layer. There is not much to document with the drainage layer. Perhaps a few sieve and constant-head permeability tests on the gravel, and the surveyor can verify that the proper one-foot thickness of the layer is achieved. Although the majority of the information was captured in the heat of the battle, it is, after all, nice to have a little time to straighten it up and get it ready for presentation in the final certification report. With occasional walk-arounds during the gravel placement to make sure that wrinkles are being kept under control, there is not much else to document.

But then the counterattack begins, and the enemy is using armored weapons! Good CQA practice dictates that a full-time observer should be stationed in front of a bulldozer blade spreading gravel over a geomembrane to watch for potential damage to the geomembrane. Although costly for the the owner and unglamourous for CQA personnel, experience has shown that this is really the most critical time of the battle; this is when the most damage can occur.

However, electrical leak location testing is an effective final defense weapon. It can be used in lieu of the visual monitoring function to detect damage that cannot be seen by CQA personnel, no matter how observant they are. Having electrical leak location testing as part of the CQA program lowers the cost of the primary author's CQA services by $0.01/ft.^{2} because a full-time monitor is not required to watch the bulldozer blade. These cost savings can partially offset the cost of the electrical leak location service, which for soil-covered geomembranes has been less than $0.05/ft.^{2} for landfill cells of at least five acres in size. And the CQA battle is finally won.

Harm caused by destructive testing

EPA technical guidance emphasizes destructive testing of seams. About four to five samples are cut out of the seams for every

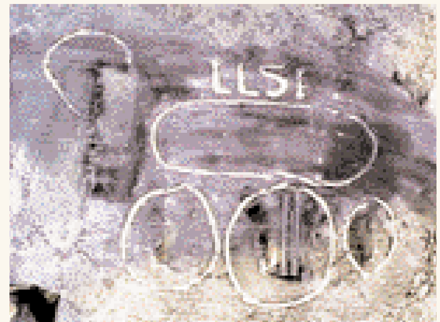

Photo Courtesy Leak Location Services, Inc.

Photo 3. A widespread problem of construction damage: Bulldozer track cuts in geomembrane.

acre of geomembrane. Each sample area is patched, which requires about 12 ft. (3.7 m) of inferior manual extrusion welding. The samples are tested for shear and peel strength at stresses that are many times higher than the stresses the seams will experience in service. Assuming a 10-acre (4-ha) landfill, 600 ft. (183 m) of extrusion welding is needed to take the samples. On average, 3% of the samples do not pass the destructive test. For the 10-acre landfill, this would mean an average of 1.5 samples not passing the destructive test. These areas would require another 63 ft. (19 m) of extrusion weld. So to test a fraction of a percent of the superior dual-track fusion welded seams, an additional 663 ft. (202 m) of inferior extrusion welding must be made on an average 10-acre landfill. This leads to the question of whether testing the 663 ft. of extrusion welds would result in another sample not passing a destructive test.

Resistance to change

If we were to objectively regard our work with the simple goal of installing a geomembrane with no defects, we would have a much more wholesome approach than blindly accepting the house of cards that the industry has dealt us. This statement is not meant to be sarcastic, nor is it meant to diminish the efforts and understanding that the industry has gained about seaming practices. Indeed, the industry is, in general, doing quite a fantastic and commend-

A plan for reducing destructive testing

- Leak location testing using electrical methods should be incorporated as a key element of the CQA program. This is the only way to verify that the geomembrane is performing its intended function after it is covered with soil. This test removes the need to have a full-time CQA monitor and also detects damage that cannot be detected with visual monitoring.
- CQA should include a limited number of destructive tests. The primary author typically specifies taking only two destructive test coupons ("bones") at either the beginning or end of each new long field seam [approximately once every 400 ft. (122m)]. One used for a shear test checks for proper elongation of the material immediately adjacent to the seam. This verifies that it has not been adversely affected by too much heat, scoring or over grinding. The other coupon is used in a peel test to verify proper bonding of the weld.
- The testing is all done in the field at a location where the temperature is maintained close to 70° F (21°C). Although strength values are not required, they are inevitably recorded out of habit. This results in instant acceptance or questioning of the seam at little to no extra cost. The locations of the destructive samples are at the ends of seams, which typically require a patch anyway. Of course, there is always the option of cutting additional destructive samples in "suspect" areas, which rarely occurs. Now CQA during seaming can be focused on inspection, making sure the seams are kept clean and dry, operator care, etc.
- In-field destructive testing of trial welds should continue to be performed to demonstrate that the welding equipment and personnel are performing properly.
- Qualification of installation and CQA personnel is an area where the reliability of the installations can be improved. By focusing on observation of seaming practices, rather than bookkeeping and paperwork, a higher level of reliability would be achieved.

able job in regard to seaming. What we have not done is reviewed our goals and reallocated our precious resources (i.e., time and money) in the best way to meet our goals. Why is this? Most likely it is simple inertia—a passive resistance to change. Anyone who introduces industry change becomes open to the fearful charge of operating "outside of current industry practice" and may feel subject to liability.

It takes a certain amount of courage to say that the emperor has no clothes. The emphasis on seam testing has focused attention away from the real problem of holes in the geomembrane. While some holes are caused by inadequate installation, much more significant are those caused by construction damage while installing a drainage/protective layer of earth materials on the geomembrane. Leak location testing shows that leaks caused by construction damage exist in most landfill geomembranes.

Nosko et al. (1996) reported on electrical leak location surveys for more than 100 sites where several thousand areas of damage were found. Of these, 73% were construction damages caused during the installation of the covering layer. Only 24% of the damage found was caused during the installation of the geomembrane, and 61% of those leaks were found mainly in extrusion welds. These data match the extensive experience gained by the authors using leak location surveys.

These examples raise serious questions about the cost/benefit of regulatory-driven CQA. Shepherd et al. (1992) felt that if the regulatory CQA requirements are not aligned with the overall concept of obtaining significant environmental protection value, then alternatives that better meet the overall objectives should be used.

The proper philosophy

Soon after the U.S. EPA provided technical guidance for QA/QC for waste containment facilities (1993), some in the industry began questioning the wisdom of performing destructive testing of dual-track fusion welded geomembrane seams, and having to repair the sample location with inferior extrusion welding (Cadwallader et al. 1994). At the same time, electrical leak location methods (Darilek et al. 1989) have been commercially available and applied to find a great number of actual leaks in geomembranes that had undergone the QA/QC detailed in the EPA technical guidance.

The function of a geomembrane liner is to prevent contaminated liquid from leaking into the environment. Although geomembranes have sufficient thickness and tensile strength to prevent punctures and to facilitate seaming, geomembranes are subject to zero or minimal tensile loads in service. In fact, the industry would be hard-pressed to cite a single documented case where a dual-track fusion welded seam in a landfill has failed in service by separating as a result of tensile stress. At the same time, there are numerous well-documented cases to show that almost all installed geomembranes have holes. It makes no sense to simply focus on providing maximum tensile strength for the geomembrane seams while ignoring actual holes in the geomembranes.

A new perspective is needed to produce optimal environmental safety at the lowest cost to owners and rate payers. The advancement of geomembrane seaming and testing technologies have made some government-mandated CQA measures outdated and even counterproductive. A proactive approach is needed to place the correct emphasis on minimizing known problems rather than mindlessly focusing on presumed problems that do not exist.

Geomembrane leak location technology

The electrical leak location method is to impress a voltage across the geomembrane, then detect the points where electrical current flows through the geomembrane. This is a well-established technology used in the CQA of geomembrane liner installations. The development of the technology was initiated by the U.S. EPA. in 1980. The first commercial leak location surveys for soil-covered and water-covered geomembranes were performed in 1985. There is an ASTM Standard Guide for selection of electrical methods for locating leaks (ASTM 2002). In addition, ASTM standards are currently being prepared for testing soil-covered, water-covered, and bare geomembranes. In the case of landfills, the method can be applied after protective drainage material is placed over the geomembrane, once the greatest potential for damage to the geomembrane has passed.

The State of New Jersey Solid Waste Regulations require an electrical leak location test of the primary geomembrane, or other post-construction method (N.J.A.C. 7:26-2A.7(a)19). For industrial and hazardous waste disposal facilities, the State of Texas strongly encourages a test of each synthetic liner using an electrical leak location system (TNRCC-0376, Rev. 07/24/2002). Other progressive states are strongly considering requiring the method or requiring it to demonstrate the performance of single geomembrane systems. For the past four years, the primary author has encouraged all of his clients in Oregon, Washington and California to use it whenever they install GCL/geomembrane composite liners.

No special geosynthetics or unusual construction techniques are required. The technology can be used with any electrically-insulating geomembrane.

There are several geomembrane leak location contractors performing services in the United States. Four are listed in the 2003 *GFR* Specifier's Guide. At least seven other firms have provided geomembrane leak location services in the United States.

Towards an optimum plan

The theme of decreasing destructive testing and increasing leak location testing has been echoed by many in industry. Some include Phaneuf and Peggs (2001), Adams et al. (2001), Thiel (2002) and Darilek and Laine (2001). The last paper showed that leak location surveys find more than six times more problems per dollar than conventional CQA.

Instead of just cutting holes in our geomembranes to test, we should be testing our geomembranes for holes and cuts. We want good seams, so some destructive testing will be necessary. But the frequency and scope of destructive testing must be drastically reduced. At this point the authors offer a bold, but reasonable plan. (See inset box on page 23.) The primary author follows this, as much as he is able, for various landfill clients on the West Coast.

Conclusions

Engineers, regulators and owners should not be allowed to develop a false sense of security from following regulations while ignoring more productive technologies. Now is the time to reexamine CQA requirements. CQA programs must be specified to produce the most benefit. Dual-track fusion welded seams have not been a problem. Industry problems associated with stress cracking next to seams have largely been addressed through improvements of resin manufacturing, not seaming practices. Construction damage, primarily caused while placing protective drainage material on the geomembrane, will always be a significant potential problem. Electrical leak location testing is an efficient and effective way to locate this damage for repair. GFR

References

Adams, M., Hulls, D., and Swyka, M. 2001. "Geomembrane construction quality assurance updated." *Geotechnical Fabrics Report*. v19, no.4, pp. 18–21.

ASTM International. 2002. "Standard Guide for Electrical Detection of Potential Leak Paths in Geomembranes." Designation D 6747–02. West Conshohocken, Pa.

Cadwallader, M., Laine, D., and Peggs, I. 1994. "Making the QA/QC paradigm more cost-effective and relevant." *Geotechnical Fabrics Report*. v12, no.7, pp. 44–48.

Darilek, G.T. and Laine, D.L. 2001. "Costs and Benefits of Geomembrane Liner Installation CQA." *Geosynthetics 2001 Conference Proceedings*. IFAI, Roseville, Minn.

Darilek, G.T., et al. 1989. "The Electrical Leak Location Method for Geomembrane Liners: Development and Applications." *Geosynthetics '89 Conference Proceedings*. IFAI, Roseville, Minn.

Koerner, R.M. 1994. *Designing with Geosynthetics*. 3rd Ed. Prentice Hall, Englewood Cliffs, N.J.

Nosko, V., Andrezal, T, Gregor, T., and Ganier, P. 1996. "SENSOR Damage Protection Damage Detection System (DDS)—The unique geomembrane testing method." *Proceedings of the First European Geosynthetics Conference, Eurogeo 1*. A.A. Balkema, Maastricht, Netherlands. pp. 743–748.

Phaneuf, R. and Peggs, I. 2001. "Landfill construction quality—Lessons learned from electrical resistivity testing of geomembrane liners." *Geotechnical Fabrics Report*, v. 19, no. 3, pp. 28–35.

Shepherd, J.A., Rivette, C.A., and Nava, R.C. 1992. "Landfill Liner CQA: A Summary of Real Costs and a Question of True Value." *Proceedings of the 6th GRI Seminar*, Philadelphia.

Thiel, R. 2002. "Current Industry Issues with GCLs" *Proceedings of GRI XVI*. Geosynthetic Institute, Folsam, Pa.

U.S. EPA. 1991. "Inspection Techniques for the Fabrication of Geomembrane Field Seams." *EPA/530/SW-91/051*.

U.S. EPA. 1993. "Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities." *EPA/600/r-93/182*.

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