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GCL shrinkage: A possible solution

By Richard Thiel and Chris Thiel

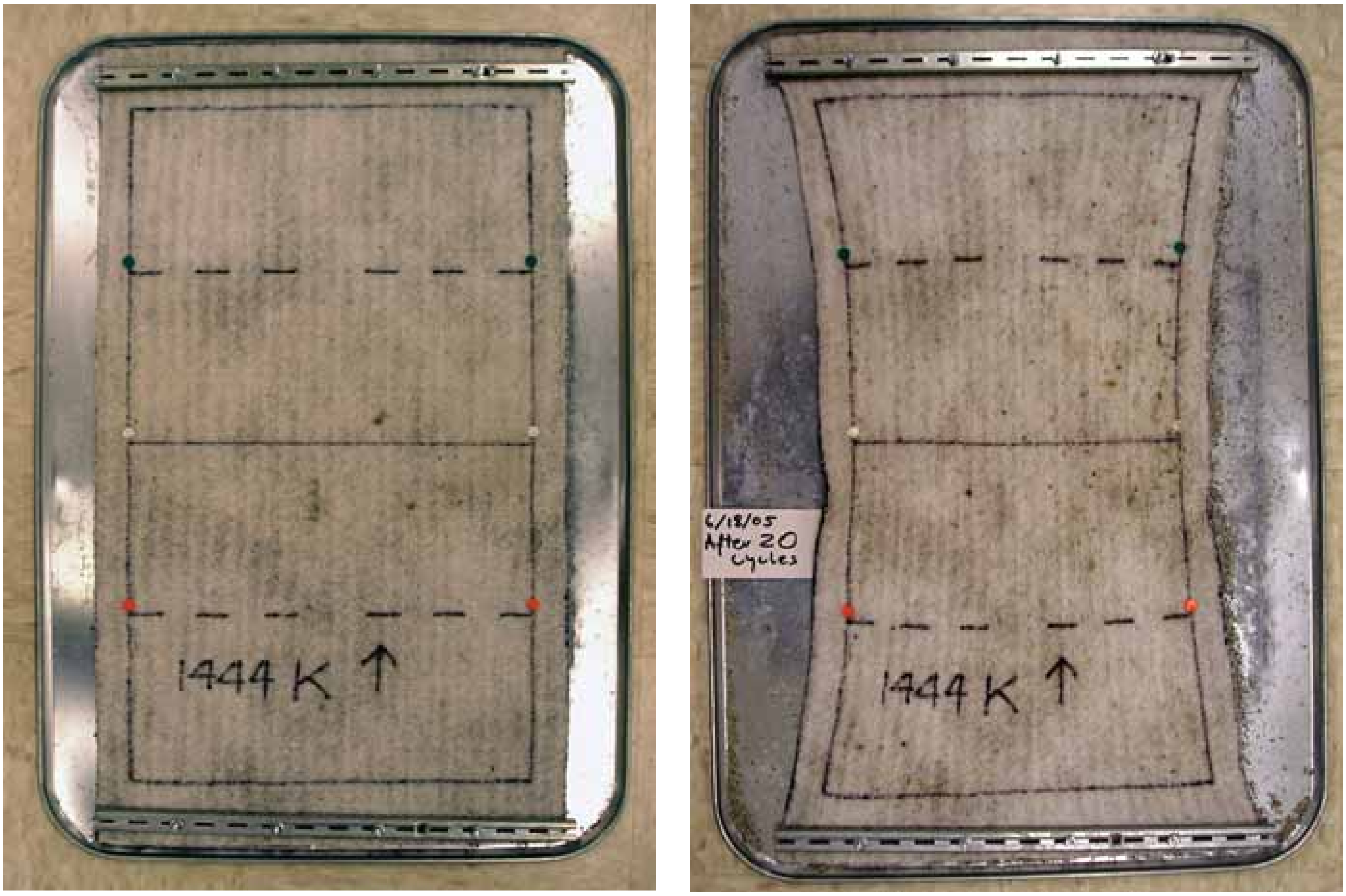

Figure 1 | GCL sample (left) before test cycles and (right) after 20 hydration-drying test cycles.

Reproduced from article by Thiel, R., Criley, K., and Bryk, J. (2005) "Practical Guidance on Specifying GCL Overlaps to Account for Shrinkage", Geotechnical Fabrics Report, V23, N8, Nov 2005, pp. 20-25.

Introduction

A potential industry-wide concern for GCL shrinkage was identified by Thiel and Richardson (2005) at the January 2005 Geo-Frontiers conference in Austin, Texas, based on observed problems at several sites worldwide. All of the known problems were for installations where an exposed geomembrane/GCL composite installation was left unballasted (that is, with no overlying cover soil) for an extended time.

Some of these "failures" have been quite dramatic, with shrinkage gaps up to 3ft between panel after panel of installed GCL, which originally had minimum 6-in. overlaps (**Figure 2**-p.11). Follow-up work reported in *GFR* by Thiel, et al. (2005) and by Thiel, et al. (2006) was able to replicate the GCL shrinkage phenomenon in laboratory tests by the application of cyclic wetting and drying. An example of the laboratory-induced shrinkage is shown in **Figure 1**.

The laboratory work indicated that various products available on the market had different propensities toward the rate

Project Highlights

Owner: Quadra Mining, Vancouver, B.D., Canada

Liner installer:
International Lining Technology Inc. (ILT), Reno, Nev.

Construction quality assurance (CQA):
Thiel Engineering, Oregon House, Calif.

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Chris Thiel is a lead CQA officer with Thiel Engineering
The Designer's Forum column is refereed by Greg Richardson, Ph.D., P.E., a principal at RSG & Associates, Raleigh, N.C., www.rsgengineers.com

Courtesy of Richard Erickson

Figure 2 | GCL gap on sideslope in California.

and magnitude of shrinkage, with asymptotic maximum shrinkage values ranging from approximately zero for geomembrane-supported GCLs, to 25% for a certain double-nonwoven GCL product. That maximum laboratory value, in fact, was approximately representative of the worst-case field exhumation observed in **Figure 2**. Even so, it has been difficult to provide definitive guidance to designers and installers on how to avoid field GCL panel separation due to shrinkage.

General recommendations have included increasing the initial overlap distance and limiting the amount of time that geomembrane/GCL installations should remain unballasted. It has generally been surmised that a minimum of 12in. of cover soil would preclude further GCL shrinkage.

The purpose of this article is to present the field techniques and observations used on a 150-acre lining installation that may provide a solution to this problem. While the precise forensics of the issue are yet to be fully explained, owners and practitioners might be able to appreciate having less to worry about in terms of cost and risk associated with GCL shrinkage.

The Carlota Mine heap leach project

The Carlota Copper Mine is under development near Miami, Ariz., approximately 80 miles east of Phoenix in the Mescal Mountains. It is owned and operated by Quadra Mining of Vancouver, B.C.

The mine started copper extraction using heap leach technology during 4th quarter 2008. This technology is used worldwide to extract metals from mined rock ore by leaching the piles of mined ore with various solutions (such as dilute sulfuric acid for copper) that dissolve the desired mineral. The bottoms of these leach piles are designed with geomembrane liners and liquid collection systems. These structures could be considered the largest man-made structures in the world

Photos 3-9: Obtained from Thiel Engineering CQA program of Carlota Copper Project Heap Leach Pad.

Figure 3 | The Carlota Mine heap leach pad under construction with approximately 150 acres of GCL/geomembrane composite liner.

in terms of volume, with one heap leach project size exceeding 40 million ft^2 of liner (Smith 2008).

The first phase of the Carlota Copper Mine heap leach pad comprises a 150-acre lined area. A photograph of the liner installation in progress at this site is shown in **Figure 3**.

The regulatory requirement for the liner system is to have a composite liner. Carlota's proposed liner system comprises a needlepunched GCL placed on a prepared soil subgrade, overlain by an 80-mil textured LLDPE geomembrane. The GCL allowed for this project required a minimum bentonite loading of 0.6 lb/sf. Although there are many other details involved with the liner system used for the sophisticated design at this

Figure 4 | Installer flame-tacking GCL edge seam having a 6-in. overlap.

Figure 5 | Installer flame-tacking GCL butt seam.

site, they are not necessarily relevant to the current discussion.

One other relevant point is that some of the areas required the use of a double-nonwoven GCL for purposes of enhanced durability and shear strength. Other areas only required a woven-nonwoven needlepunched GCL, which was slightly less expensive. This is relevant to the current discussion because both were evaluated for potential shrinkage.

GCL overlap requirements at Carlota

This initial design specification considered an industry-standard 6-in. overlap for the seams on the GCL. During the design and constructability review process, the potential issue of GCL shrinkage was raised. The concept of increasing the

Figure 6 | Some areas of liner that were unballasted and some areas covered with overliner material.

Figure 7 | Exhumation of GCL overlap on slope that had been unballasted for more than 60 days. The heat-tacked seam was intact.

overlap was discussed, but on a 150-acre project any increase in overlap would have significant material cost implications.

To address this issue, a goal was established to have overliner (the term for the cushion and drainage layer on top of the geomembrane) placement occur within 30 days of liner deployment. Note that the term "liner deployment" in this case refers to the GCL and geomembrane composite. Both layers were essentially deployed simultaneously since the geomembrane could not be deployed before the GCL, and it was not allowed to have deployed GCL left uncovered overnight without an overlying geomembrane.

At the beginning of construction, it became apparent that the 30-day exposure rule would likely be violated. That is, it would be logistically difficult to insure that adequate overliner production

GCL Sample	Seam shear (ppi)	Seam peel (ppi)
Double nonwoven	14	24
	8	18
	18	12
Woven/nonwoven	7	21
	5	21
	4	9

Table 1 | Exhumation of GCL overlap on slope that had been unballasted for more than 60 days. The heat-tacked seam was intact.

would be maintained to have the liner installation covered within 30 days.

This issue was discussed on the first day of liner deployment, whereupon the liner installer volunteered a proposal to heat-tack all of the GCL seams at no additional cost. The installer suggested that the heat tacking could be done quickly and easily, and would provide ample restraint against the GCL shrinking.

This proposal was put forward to allow the mine to maintain the specified 6-in. overlap and increase the allowable unballasted exposure time to 60 days. The mine agreed to allow the CQA firm to verify that the GCL overlap was being maintained by cutting open areas of unballasted liner as they approached the 60-day time limit.

Seaming method and results

The installer heat-tacked every GCL seam with a quick application of a flame torch followed immediately by light pressure. The heat-tacking was continuous along all overlaps.

Figures 4-p.12 and **5**-p.14 show the installation technician heat-tacking the seam with a torch, followed by a light pressure either by dragging a sandbag over the seam or foot pressure to press the seam together after the torch. The technician could walk along at a steady pace to create the seam; thus the process added negligible material cost (a small amount of propane) and not much labor.

During the course of the project, many areas of the 150-acre-lined leach pad went up to, or even exceeded, the 60-day unballasted time frame guideline. **Figure 6**-p.14 shows an example of the large areas of unballasted liner and areas that had overliner during one point of the construction project. To verify that the GCL had not shrunk, the CQA firm cut holes through the geomembrane to exhume the GCL in areas that had been unballasted for more than 60 days.

This was performed in 6 separate areas of the project, all on midslope locations, between the months of February

Figure 8 | Photos showing location on long slope where GCL was exhumed, and the exhumed seam (orange dots in middle of slope are people cutting the geomembrane). GCL was observed to be hydrated, and the heat-tacked seam was intact.

Figure 9 | Performing shear and peel tests on 1-in. wide strips of heat-bonded GCL seams.

> **…this investigation was a bold full-scale observation of the potential for GCL shrinkage on a large project with large consequences.**

and June. Weather conditions during this time fluctuated from below 30°F to above 90°F.

Figures 7-p.16 and **8**-p.18 are photos of some of the areas that were exhumed and sampled. Both the double-nonwoven, and the woven-nonwoven GCL products were evaluated as part of this investigation. In every instance, zero evidence of any GCL shrinkage was noted. The original heat bond of the GCL seam, created by the flame-torch tacking during deployment, was intact in every case.

Although there was no specification on the required amount of heat tacking, samples of the heat-tacked GCL seams were cut out and subjected to shear and peel tests in the field. One-in.-wide samples were razor-cut and tested as if they were geomembrane coupons, as shown in **Figure 9**, yielding the results in **Table 1**-p.16.

Discussion

The lack of documented shrinkage in this project cannot necessarily be attributed to the heat-tacking alone, any more that anyone can explain why shrinkage may or may not occur in other instances.

Other factors of why shrinkage may not have occurred on this project could have been:

a) aggressive texturing of the overlying 80-mil LLDPE geomembrane.
b) lower bentonite content of the GCLs compared to other projects.
c) nature and moisture of subgrade soils and weather conditions at the site.
d) perhaps 60 days was too short of a time frame.
e) other things we do not understand.

Those admissions being made, it has to be acknowledged that this investigation was a bold full-scale observation of the potential for GCL shrinkage on a large project with large consequences. By allowing cutting of the liner to inspect the GCL seams after 2 months of unballasted conditions, the mine owner was able to maintain material cost savings in GCL overlaps and have the confidence that the job was performed correctly as designed.

The creative suggestion and cooperation of the installer to provide the heat-tacked seams was a gesture of teamwork on a large project, and it offers a potential solution for other projects in the industry. It was a pleasure to be able to work with such a proactive owner and cooperative installer.

Flame-tacking of GCL seams is now part of the lead author's standard specifications for all of his containment design projects. He also recommends this in design and CQA reviews on other projects. Why not? It costs next to nothing, has no negative implications on the installation, and may have a large benefit.

Since the original submittal of this article to *Geosynthetics* magazine, the lead author has been coordinating with Dr. Kerry Rowe at Queen's University in Ontario, Canada, on additional laboratory research into the strength of the heat-bonded GCL seams and their ability to resist worst-case shrinkage forces induced by laboratory conditions. The data is promising and an update will be presented and published at the Geosynthetics 2009 conference February 25–27 in Salt Lake City.

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