GCL Shrinkage[i]

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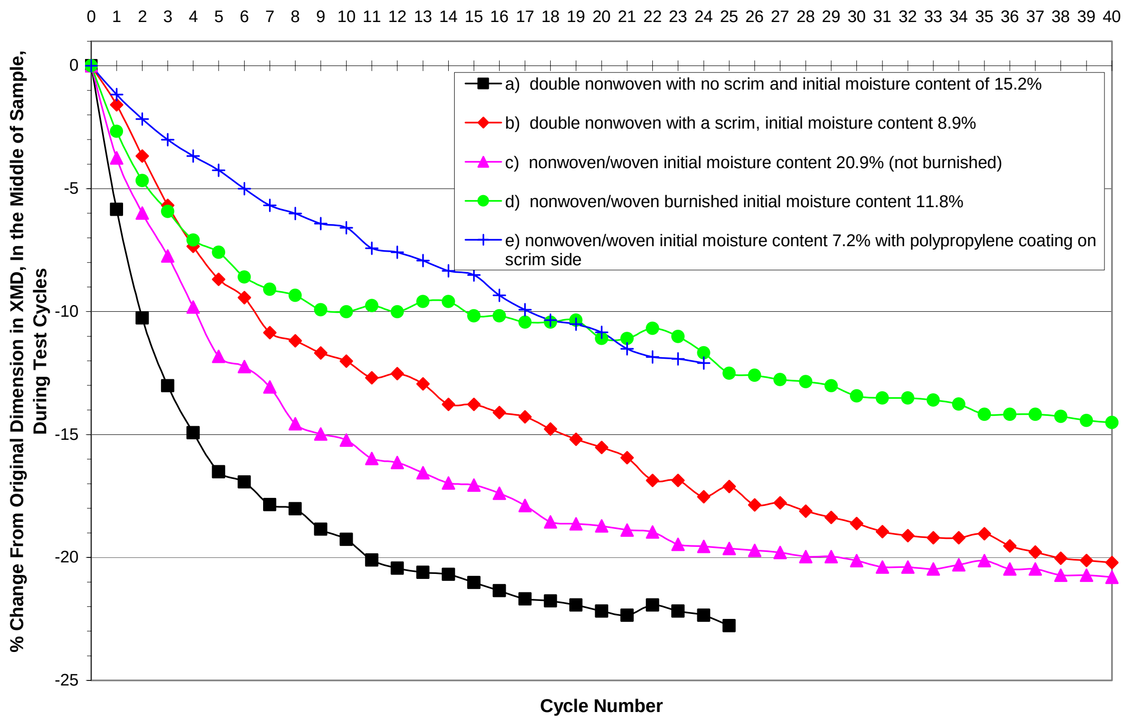
Shrinkage of unreinforced geosynthetic clay liners (GCL) in the field has been acknowledged and managed for many years; however, the awareness of panel shrinkage of reinforced GCL products is very recent. The first published acknowledgement of this issue for reinforced products was in 2005 (Thiel and Richardson) which mentioned five incidences of GCL panel shrinkage that had been discovered in the fast few years. All the cases involved reinforced GCLs that had initially been overlapped 6 inches, and then were covered with a geomembrane, which was left exposed for extended periods of time (two months to five years). For various reasons, the owners of these facilities had to cut open or remove parts of the geomembrane, at which time they discovered that the GCL panels had shrunk in the widthwise direction from 10 inches to over 3 feet.

In a white paper on the topic, the Geosynthetics Institute (GSI) suggested these mechanisms: (1) Shrinkage "*perhaps accompanied by cyclic wetting and drying*"; (2) longitudinal steep-slope tensioning; and (3) contraction on relatively flat surfaces. The white paper strongly emphasized the steep-slope tension-necking as the leading causative mechanism leading to GCL panel separation. For the one mining case in South America that experienced very large amounts of separation on a regular basis on relatively flat slopes, they conjectured that GCL "*panel contraction*" was caused by expansion and contraction of the overlying textured geomembrane, which may have "*gathered*" the GCL and caused it to bunch up.

Wet-Dry Cycling

Shrinkage by drying is not a new phenomenon. The authors' firm has experienced this while performing CQA on projects with these types of materials, where dramatic shrinkage would occur from the beginning of the day to the end, with complete loss of overlaps. This phenomenon was first published in 1997 and manufacturers of unreinforced GCLs caution about it in their literature. For reinforced GCLs one drying cycle has not been observed to create such a problem. Our studies indicate a maximum shrinkage of approximately 2% with one drying cycle. However, the field-observed shrinkage was, in some cases, more than 10 times this amount. This same testing found that cyclic wetting and drying can have a profound impact on shrinkage. Figure 1 shows the results of laboratory testing for cyclic testing for five different reinforced GCLs. Multi-cycle shrinkage ranged from 14 to 23%, consistent with field observations.

Figure 1: Comparison of Dry-Cycle Shrinkage Results of 5 Different Products



Cyclic wetting and drying can be caused by the diurnal temperature swings, which can be very large under a geomembrane. Daytime temperatures can reach 60 or 70°C on black geomembrane, while night time temperatures will be about ambient. This will cause cyclic vapor/condensate phases with a resulting cyclic change in water content in the GCL. Longer-term, the GCL can exchange water with the subgrade, depending on their relative matric-suction properties.

Tension-Necking

The GSI laboratory testing indicated that any tension induced in the products will exacerbate potential necking problems, which is logical. Tension-necking was surmised to be the leading causative mechanism for panel separation at the Badlands project in California which had very steep slopes, approaching 1.5[H]:1[V]. The authors have also observed some down drag of an unrestrained GCL on a 2:1 slope that appeared to be caused by the diurnal expansion and contraction of the overlying textured geomembrane. However, of the five cases published this year one was a relatively flat installation and one of the sloping installations had direct measurements that indicated no drag down affect. Thus, at least two of the five cases were not suspected to have tension in the GCL. More generally, our own CQA operations commonly find evidence of liner drag down on slopes but it is rare to find this for GCLs.

Current Laboratory Test Program

The results for five GCL samples are presented in Figure 1. Given the range of shrinkage measured and considering a 15-foot wide panel, shrinkage of 1.5 to 3 feet would result. This is consistent with field observations. To date our laboratory testing program has been performed on 5 different fabric-encased GCL products, one geomembrane-backed GCL. One product was tested with two different amounts of water being added. The range of response for the fabric-encased GCLs is about a factor of two. The geomembrane-backed GCL did not shrink. We have observed a slower rate of shrinkage-per-cycle when less water is added, as would be expected. Testing of additional products and matrix variables is ongoing.

Admittedly, the results depicted in Figures 1 probably represent worst-case conditions. It is unlikely that most installations would receive as much water as was added during the test, and then be dried to the extent performed in the test on a regular basis. A more likely scenario is that the magnitude of wetting and drying would be smaller on a day-to-day basis. On a seasonal basis, however, it is plausible that there may be extended periods of cool, overcast weather that would allow a fairly complete hydration of the GCL. Conversely, there may be extended periods of hot sunny weather that substantially dry the GCL. Thus, there may be small daily cycles superimposed on more significant seasonal cycles. This area definitely needs more research. A critical area that may experience the extremes simulated in the testing is at the toes of slopes, as described below.

How Much Overlap is Needed?

Although the data from this study is preliminary, the authors believe it is appropriate to publish at this time to help designers and manufacturers get a handle on the answer to the question: How much overlap is needed? Although we cannot answer this question explicitly at this time, we can point to the following variables that would influence the answer:

- The amount of shrinkage is likely related to the number of days that the liner system is left exposed without soil cover. We are assuming that shrinkage only occurs when a GM/GCL installation is exposed, and that it is not an issue when the installation is covered with a minimum of 12 inches of soil.
- The amount of shrinkage is likely related to the moisture conditions of the subgrade and exposure to direct sun.
- The amount of tension necking is likely related to the steepness of the slope and *Velcro*-effect of the overlying geomembrane.
- The amount of shrinkage is product-specific, with double-nonwoven products containing no woven geotextile being the most susceptible to shrinkage from both wet-dry cycling and tension-necking.

At this point the authors are recommending greater than 6-inch overlaps on most projects, and considering 12 inches overlap as a standard minimum design basis. Allowing or requiring less or more overlap than 12 inches would be considered in light of the project-specific variables. Project specific overlap needs can be estimated as follows:

1. Select the GCL products to be tested and obtain representative samples of each;
2. Determine the maximum time duration that the GM/GCL installation will remain exposed with no soil cover. Presume that every day represents one wet-dry cycle. Admittedly this will be conservative, but at this time the authors do not see another rational choice for the selection of the number of cycles.
3. Estimate the maximum daily temperature that the exposed geomembrane will experience. Absent other data assume that exposed black-surface geomembranes would achieve 60°C, and white-surface geomembranes would achieve 40°C.
4. Estimate the amount of water to add for each cycle. This is the most difficult parameter to estimate. Typically there are only two sources for water: (1) the initial water in the GCL, and (2) subgrade soil moisture. If the GCL is polymer-coated on its bottom side, or installed encapsulated between two geomembranes, then only water that evaporates out of the GCL during the drying cycle would be available for re-wetting. If an uncoated GCL is installed against a soil subgrade, then estimate the available water based on the water content of the upper 3 to 12 inches of subgrade.

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