GEOSYNTHETIC CLAY LINER (GCL) PANEL SEPARATION UNDER EXPOSED GEOMEMBRANES: AN UPDATE FOR DESIGNERS OF LINING SYSTEMS

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SUMMARY

Geosynthetic lining systems based on composite liners incorporating geomembranes and low permeability soil layers (including GCLs), have commonly been designed to leave the lining system uncovered, the contents of the facility thus being in direct contact with the primary geomembrane liner which is exposed until covered with the contained material. Negative impacts of this approach are being identified, including *inter* alia lack of intimate contact between geomembrane and soil layer, and GCL overlap joint separation.

1. INTRODUCTION

Geosynthetic clay liners (GCLs), which were first used in the early 1980's and came into general use later in that decade, have become an important addition to the design engineer's toolbox. These low permeability linings rely on a layer of bentonite that is confined between geosynthetic carrier and cover layers as the 'active ingredient'. They are widely accepted as being able to replace or supplement thick compacted clay liners (CCLs) in many applications, including those used for liquid and gas containment in waste management facilities (Koerner 1995).

In lining applications, CCLs and GCLs have been shown to function optimally when used in *intimate contact* with a geomembrane, the combination of the two being described as a *composite liner*. When so used, the reduction in permeability of the lining system has been shown to be orders of magnitude lower than the permeability exhibited by CCLs, GCLs and geomembranes when these are used as stand-alone liners. It is now commonly accepted that GCL-geomembrane composite liners exhibit the lowest permeability of any commonly used lining system, whatever the application (Koerner & Daniel, 1995).

However, as with all construction materials there are issues around their use, and among the issues around GCLs is panel joint separation as discussed here. Another is an ion exchange issue whereby the Sodium bentonite in the GCL is converted to a less active Calcium bentonite in service, with an attendant increase in permeability. Meer and Benson (2007) have recently highlighted this long-known phenomenon in some landfill capping projects. It is a complex issue beyond the scope of this paper, and for more detailed and scientific information on this topic, readers are also referred to Eggloffstein (2001 & 2002) and Bouazza et al (2006).

2. GCL PANEL SEPARATION

Some recent investigations by Koerner (2005a, 2005b) and Thiel (2006) reveal that the practise of designing containment structures that incorporate an uncovered geomembrane overlying a GCL layer can result in the GCL panels underlying the primary geomembrane shrinking to an extent that causes GCL panels to part in the overlap area. This is cause for concern, as the *composite lining* effect in the parted overlap region is negated. An important observation is that the separation problem has not been found to occur on lining systems that have been adequately covered with soil or other confining layers. This paper touches on some references that have been published on the matter to date, and presents their suggestions on what can be done to avoid the GCL shrinkage phenomenon. The paper does not profess to analyse the references in detail, but merely to bring a potential

problem to the attention of local design engineers.

Pictures 1 & 2: Examples of the GCL panel separations as described by Koerner (2005a)

Koerner and Thiel have shown that the type of manufacture of GCL used, the slope angle that the system lies on, the type of overlying geomembrane and the time the system has been in place have (among several other factors) been shown to be contributing factors to the shrinkage phenomenon. This shrinkage can range from a few millimetres to over 300 mm, and in an extreme case to well over a metre – see Table 1. It is noted that the American Society for the Testing of Materials is now considering a standard test method to determine the potential for this type of shrinkage in a given GCL (ASTM 2006).

Table 1 – Known Panel Separation Cases (Koerner 2005a)

Date (Duration of Exposure)	Location	Slope	GCL Type (geotextiles)	Geotextile Orientation	Moisture (%)	Maximum Separation	Comment
1993 (5 yrs.)	Massachusetts	2.5:1	Nonreinforced (double woven)	W-up W-down	≃ 20	300 mm (12 in.)	Toe Wave
2000 (5 mo.)	Virginia	3:1	Reinforced (double nonwoven)	NW-up NW-down	24-31	300 mm (12 in.)	Slide
2001 (≃ 15 mo.)	Confidential	3:1	Reinforced (nonwoven-woven)	NW-up W-down	25-30	200 mm (8 in.)	Toe Wave
2004 (2 mo.)	So. America	2 °- 4°	Reinforced (double nonwoven)	NW-up NW-down	29-44	150 mm (6 in.)	Wet-Dry
2004 (3 yrs.)	California	1.5-1	Reinforced (double nonwoven)	NW-up NW-down	25-29	1200 mm (47 in.)	Toe Wave

The nonwoven geotextiles used in the manufacture of the relevant GCLs were of the needlepunched type, but none of the GCLs had any type of woven "scrim" reinforcement, i.e., they were not composite geotextiles of the type illustrated in Fig 2.

There are a number of manufacturers of GCLs, whose products, recommended installation and jointing techniques are distinctly different and which exhibit different degrees of panel shrinkage under the conditions described, as can be seen in Table 1 above. An understanding of how these products are structured and joined on site is important if the phenomenon of GCL panel separation is to be fully understood and avoided. However, for clarity, only the types of GCL investigated by Koerner and Thiel that are in common use in Southern Africa will be examined. For clarity, large–format sketches will be shown, as at present none of the manufacturers involved clearly show their GCL construction in detail pictorially in readily available public documents.

3. GCLS COMMONLY USED IN SOUTHERN AFRICA

3.2. Needlepunched GCLs incorporating *powdered* bentonite

3.2.1. Nonwoven *cover* geotextile / woven *carrier* geotextile type

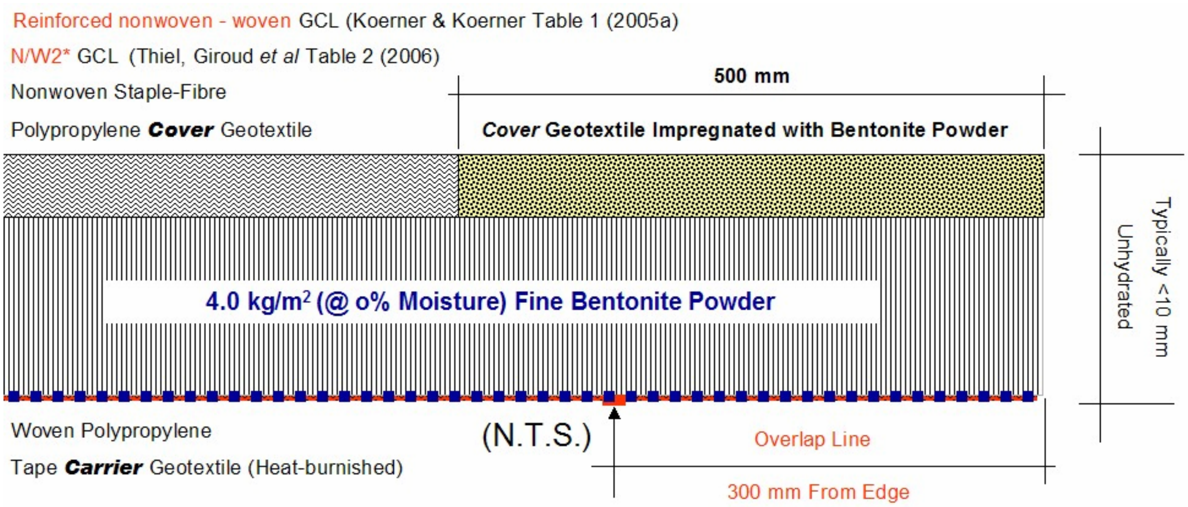

Figure 1: GCL type nonwoven cover / woven carrier

The type of GCL shown in Fig1 is manufactured by different manufacturers in several countries (including in South Africa from October 2007) and has commonly been used in southern Africa.

Table 2. Summary of GCL shrinkage values after drying (Thiel 2006)

Product (Cap GT/Carrier GT)	Shrinkage (%) No. hydration-drying cycles				
	1	5	10	20	40
Nonwoven/Woven					
N/W1	3.7	11.8	15.2	18.7	20.6
N/W2*	2.7	7.6	10.0	11.1	14.5
Nonwoven/Nonwoven					
N/N1	5.8	16.5	19.3	22.2	23.0
Nonwoven/Scrim-Nonwoven					
N/S-N1*	1.4	5.3	7.8	10.4	12.9
N/S-N2*	1.6	8.7	12.0	15.5	19.2
N/W PP Coating					
N/W-C1	1.2	4.3	6.6	10.8	12.8

* Heat-burnished carrier geotextile.

In the Koerner reference (2005a), the GCL shown in Fig.1 is the GCL type referred to as "Reinforced nonwoven-woven", and in the Thiel reference as NW/2* (Thiel 2006). In both references, the word "reinforced" refers to the fibres connecting cover and carrier fabrics due to manufacture by needlepunching and not to the woven ***carrier*** geotextile component (both of which are considered to have an influence on the shrinkage behaviour of the GCL)

3.2.2. Nonwoven *cover* geotextile / nonwoven + woven composite *carrier* geotextile

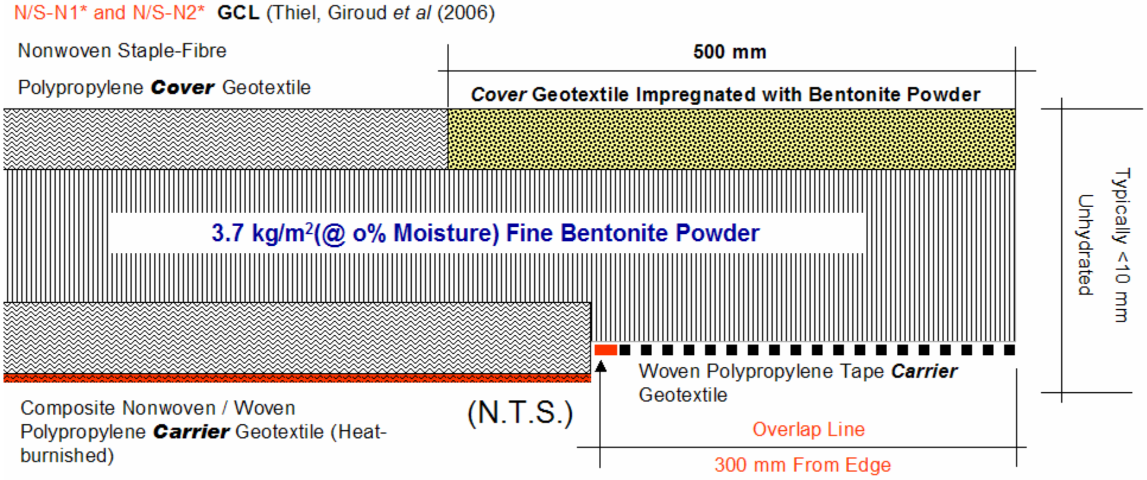

Figure 2: GCL type nonwoven cover / woven+nonwoven composite carrier

The type of GCL shown in Fig 2 is manufactured by different manufacturers in several countries (including in South Africa from October 2007) and has commonly been used in southern Africa. In the Koerner reference (2005a) none of this type of GCL was investigated. This is the GCL type referred to by Thiel (2006) as "Nonwoven/Scrim-Nonwoven", In Koerner, the word "reinforced" refers to the fibres connecting cover and carrier fabrics due to manufacture by needlepunching and not to the woven ***carrier*** geotextile component. Of this type, Thiel (2006) has this to say: "*The N/S-N samples incorporated a scrim woven fabric into the nonwoven carrier geotextile. It is generally suspected that the presence of a scrim reduces shrinkage when compared with the nonwoven-nonwoven product. In fact, incorporation of a scrim into a nonwoven carrier is discussed and recommended by Koerner and Koerner (2005a, 2005b), and also in the GRI-GCL3 standard specification for GCLs (GRI 2005).*"

3.2.3. Common jointing technique for long panel edges of nonwoven *cover* geotextile / woven *carrier* geotextile GCL type and nonwoven *cover* geotextile / woven + nonwoven composite *carrier* geotextile GCL type

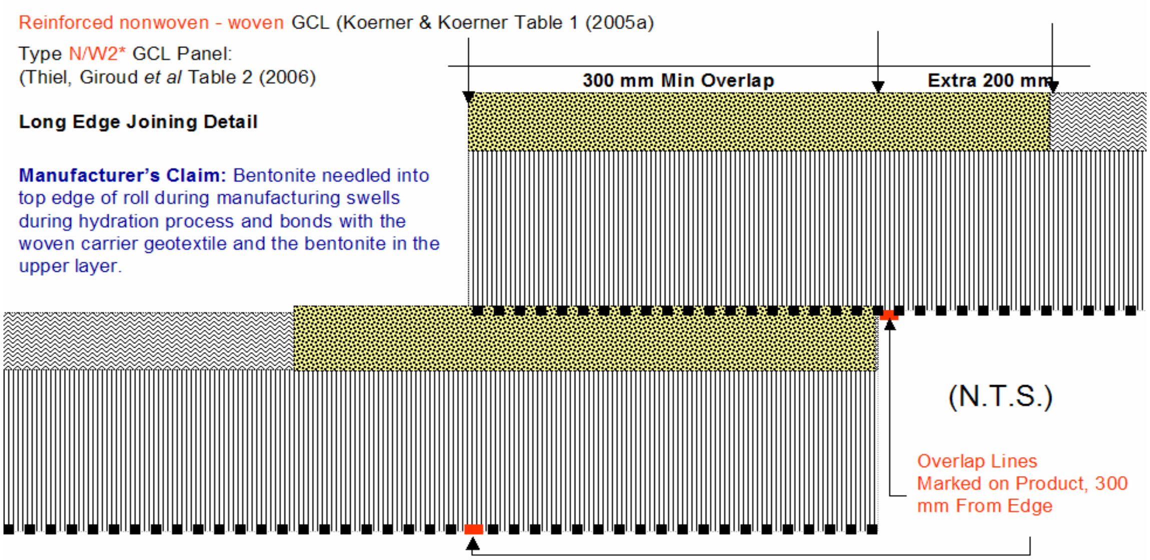

Figure 3: Jointing technique for GCLs shown in Fig 1 and Fig 2

Fig 3 shows the method specified by all the manufacturers of the GCL type described under subheading 3.2. Under confining pressure, It provides a bentonite paste joint over the full 300 mm panel overlap area and the manufacturers show that research has demonstrated that on this type of GCL the permeability of a joint constructed in this manner is less than that through the GCL sheet itself (Naue 1998).

4. Discussion on GCL overlap jointing techniques

All GCL products use the overlapping technique for constructing joints between GCL panels, whether techniques as shown in 3.2.3 or in 4.2.2, or such as by introducing additional bentonite into the lap area are used. These systems have been demonstrated to be effective (Naue 1998), (CETCO 2002), but because they rely on a bentonite paste presence between the upper and lower GCL panels they do not exhibit any significant joint strength. Due to this, any forces that act to shrink the GCL panel width cannot be transmitted from one panel to the next, and if the GCL panels are not restrained from constricting (e.g. by a confining load or an internal reinforcing component such as a woven scrim), the overlap areas can reduce or move apart.

4.2. Needlepunched GCLs incorporating *granular* bentonite

4.2.1. Woven *cover* geotextile / nonwoven *carrier* geotextile type

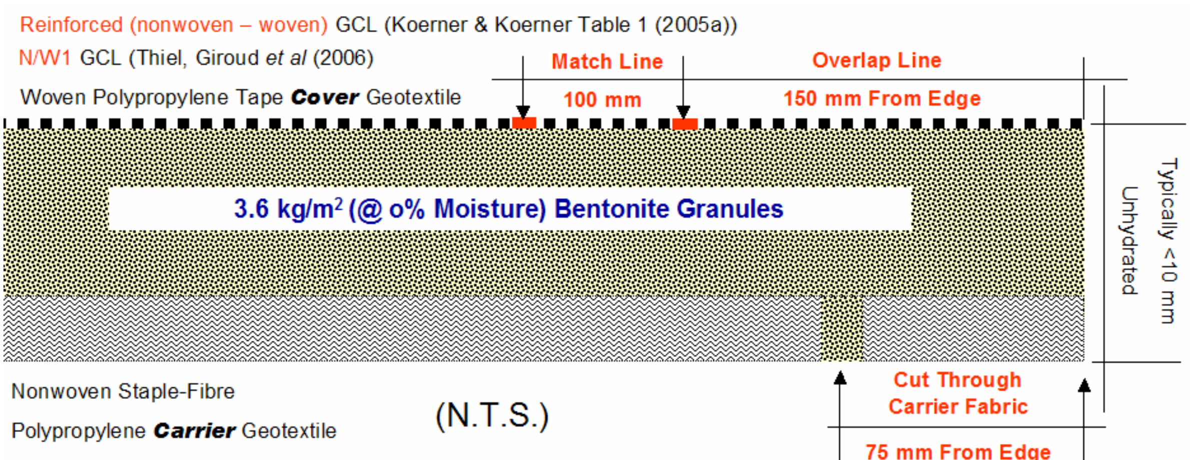

Figure 4: GCL type nonwoven *carrier* / woven *cover*

This type of GCL is made by a multinational manufacturer in several countries and has commonly been used in southern Africa. In the Koerner reference (2005a), this is the GCL type referred to as "Reinforced nonwoven-woven", and by Thiel (2006) as "Nonwoven/Woven". In Koerner, the word "reinforced" refers to the fibres connecting cover and carrier fabrics due to manufacture by needlepunching and not to the woven ***cover*** geotextile component.

In the manufacturing process these products are made in the same way as those shown in Figures 1 &2, where the nonwoven component is actually the cover material during manufacture. However, the suppliers of this type of material usually recommend that it should be laid with the nonwoven component facing down, when it then acts as the carrier.

4.2.2. Jointing technique for GCL product shown in Figure 4.

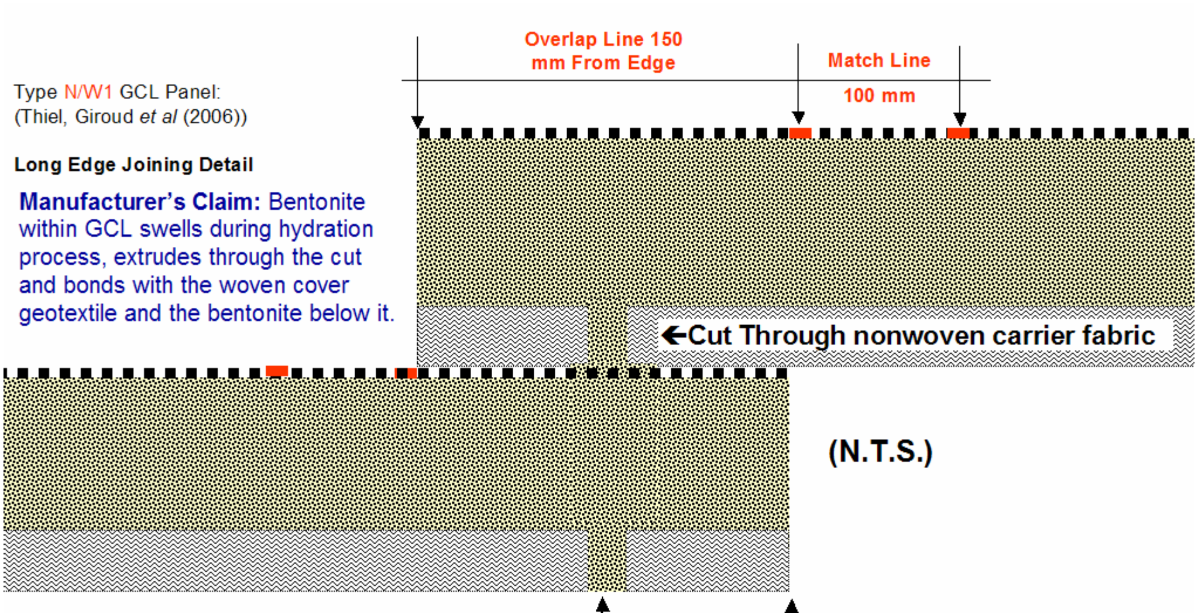

Figure 5: Jointing technique for GCLs shown in Fig 4

The jointing method shown in Fig. 5 is the method specified by the manufacturers of the GCL type described under subheadings 4.2.1 and 4.2.3. The manufacturers call for a *minimum* of 150 mm overlap. Under confining pressure it provides a bentonite paste joint over an overlap area determined by how much bentonite can be extruded through the cut under a given pressure. The manufacturers show that research has demonstrated that on this type of GCL the permeability of a joint constructed in this manner is less than that through the GCL sheet itself (CETCO 2001a &b).

4.2.3. Nonwoven *cover* geotextile / nonwoven *carrier* geotextile type

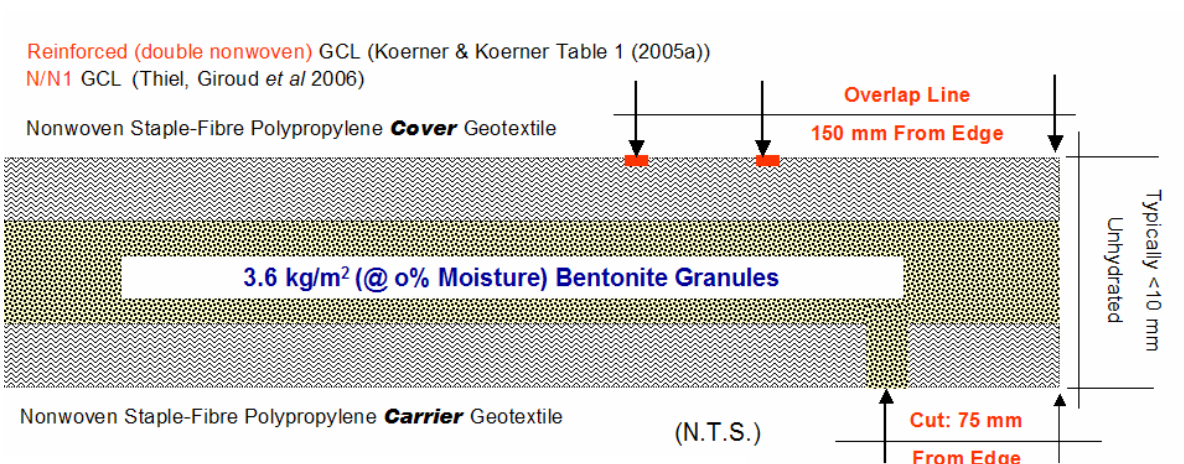

Figure 5: GCL type nonwoven *carrier* / nonwoven *cover*

This type of GCL is made by a multinational manufacturer in several countries. In the Koerner reference (2005a), this is the GCL type referred to as "Reinforced double nonwoven" and it is stated by the manufacturer that the joining technique is similar to that shown in Fig 5.

5. NON-DESTRUCTIVE IDENTIFICATION OF GCL PANEL SEPARATION ON EXISTING PROJECTS

It is not known whether any of the problems illustrated in this paper have occurred in South Africa, which leads to the question: is there anything that can be done to detect whether GCL panel separation has occurred under exposed geomembranes on existing projects, without having go the disruptive route of cutting open the geomembrane (and then repairing it) to expose the GCL layer?

Koerner (2005a) says: "*Develop a NDT Method to Detect GCL Panel Separation - There are several nondestructive testing methods (NDT) available that might be used to investigate if GCL panel separation has occurred in the field, without physically removing the overlying geomembrane. GSI is currently investigating ground penetrating radar (GPR) and ultrasonic pulse-echo methods . . .*"

I-Corp International (an independent international geosynthetic materials performance consulting and testing company) believes that infrared thermography is a technique that can be used to do this. On their web site, a number of pictures, some of which are shown below, demonstrate his work on this (Peggs 2007).


Figure 1

Picture 3. GCLs with overlap & gap

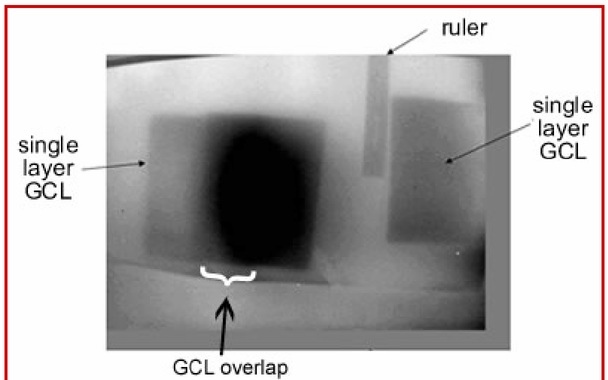

Figure 3

Picture 4. Infrared Thermograph

Dr. Ian Peggs of I-Corp, In a recent personal discussion with the author, says that while he has not used this technique on an actual project at time of writing (August 2007), he sees no reason why it would not be practical to use this technique on site – and he is looking for an opportunity to do so.

6. CONCLUSIONS

Apart from the GCL panel shrinkage problems illustrated by Koerner and Thiel, there are many good reasons not to leave composite liners uncovered and exposed. Probably the most important one is that an unconfined geomembrane acting as a component of a composite lining system is almost certain under changes of temperature to develop waves and folds which separate the geomembrane from the low permeability soil (or GCL) below, thus destroying the composite lining effect.

Another very good reason to eschew uncovered systems is the fact that GCLs *require* a confining pressure in order to function optimally. The higher the confining pressure, the lower the permeability exhibited by the GCL and this is true for all of them.

While the process of covering a composite lining system does increase the risk of damage to the installed liner, a geomembrane liner with a hole in it and which is part of a composite system will not leak very much (Giroud 1994). If the installation is properly monitored this approach is much more likely to result in a properly-functioning system than will an exposed system which is subject to many mechanisms which could damage it over the life of the project.

This paper was not written to analyse the information presented by Koerner and Thiel in detail, but merely to bring those references to the attention of South African design engineers who are not already acquainted with them. The Koerner reference is freely available on the web at: http://www.geosynthetic-institute.org/papers/paper5.pdf and the Thiel reference is available on request from the author for those who do not have access to the IGS Yokohama proceedings.

In respect of GCL panel separation, Koerner (2005a) suggests:

- "*Increase the GCL overlap to compensate for the potential panel separation. With the exception of the California case, an increase of 100 mm (4 in.) to 300 mm (12 in.) would have been adequate in the other cases. Thus, the overlap line printed on the GCLs during manufacturing should increase from the present minimum of 150 mm (6.0 in.), to between 250 mm (10 in.) and 450 mm (18 in.) depending on the GCL product used.*"

- *"Do not leave GM/GCL composite liners exposed to the atmosphere. Soil backfilling with at least 300 mm (12 in.) of soil in a timely manner (which is very much site-specific) should be adequate in this regard. This engenders other issues, such as cover soil stability, but they are site-specific design concerns . . ."*

- *"Do not use GCLs with needlepunched nonwoven geotextiles on both sides unless one of the geotextiles is scrim reinforced. There are numerous possibilities in this regard, but all should have a woven component embedded within, or bonded to, the nonwoven component".*

- *"Protect the exposed GM/GCL composite during its exposure time by using thermal blankets, geofoam, or other insulation techniques."*

Thiel (2006) suggests:

- *"The test results presented in this paper show that the presence of a woven fabric in a GCL, whether it is a woven carrier or a scrim associated with a nonwoven carrier, reduces the amount of shrinkage."*

- *"The test results also suggest that increased needlepunching results in a lower tendency for shrinkage. It also appears that a PP geofilm coating may have a beneficial effect on reducing shrinkage potential."*

- *"It is worth noting the difference in results between GCLs of the same type, but from two different manufacturers. At this point, it is difficult to determine the reason for the difference. Many variables would need to be considered, including type and granularity of bentonite, initial water content, type of geotextile fibers, methods of needle punching,* *tension on the geotextile components of the GCL during manufacturing and roll windup, etc."*

It is emphasised that this paper was written to bring the existence of the Koerner and Thiel investigations to a wider South African audience, and it is strongly recommended that those who do not already have copies of them obtain them before considering designing any containment that may incorporate uncovered composite liners incorporating GCLs.

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