Adhesion from supplemental bentonite placed at GCL overlaps

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ABSTRACT
Results are presented from a new index test conducted to measure the in-plane shearing resistance of four different overlapped GCL seams with supplemental bentonite after being exposed to one wetting and drying cycle. All GCLs required tensile force to overcome the adhesion that developed between the supplemental bentonite and the upper and lower geotextiles of the GCLs and separate the overlap. While three of the GCLs tested showed similar results, the lowest adhesion was measured for an overlap that involved a slit-film woven geotextile where the needle-punched fibres from the GCL were thermally melted to the woven geotextile which produced an interface that was less effective in bonding with the supplemental bentonite.

RÉSUMÉ
Les résultats sont présentés dans un nouveau test index effectué pour mesurer la résistance tondre en plan de quatre différent coutures des géosynthétique bentonitique (GSB) avec la bentonite supplémentaire après un cycle de mouillage et un cycle de séchage. Tous les GSB a nécessités la force de traction pour surmonter l'interaction physique qui a développé entre la bentonite supplémentaire et les géotextiles supérieure et inférieure des GSB et de séparer le chevauchement. En moyenne, la plus grande force a été mesurée pour le chevauchement des non-tissés géotextiles aiguille-perforés qui n'ont pas été traités thermiquement alors que la supplémentaire bentonite qui on été hydratée et plus tard séchées était plus capable d'ancrer entre les fibres discontinues des géotextiles. L'adhérence plus bas a été mesurée pour un chevauchement qui cause une fente film géotextile tissé lors que les fibres aiguille-perforés de GSB ont fondu thermiquement aux tissus géotextiles qui a produit une interface qui était moins efficace en liaison avec la bentonite supplémentaire.

1 INTRODUCTION

1.1 Geosynthetic Clay Liners

A composite liner consisting of a geosynthetic clay liner (GCL) beneath a geomembrane (GM), Figure 1a, can be a very effective barrier to contaminant transport in a municipal solid waste landfill. GCLs are normally only 5 to 10 mm thick and typically consist of upper and lower geotextiles with a central layer of bentonite. These three layers are most commonly joined by needle-punching and in some products the needle-punched fibres may be thermally fused to the carrier geotextiles. The GCLs are installed at a low initial water content and the bentonite then hydrates over time, taking moisture from the underlying soil material (e.g., Daniel et al. 1993, Rayhani et al. 2008).

The primary function of the GCL is to limit the leakage (i.e. movement of fluid under a hydraulic gradient) through any holes that may develop in the geomembrane (Rowe et al. 2004). Thus consideration of the hydraulic conductivity of the GCL to water, municipal solid waste leachate or other possible permeants (e.g., Petrov and Rowe 1997, Shackelford et al. 2000) is important to obtain good liner performance.

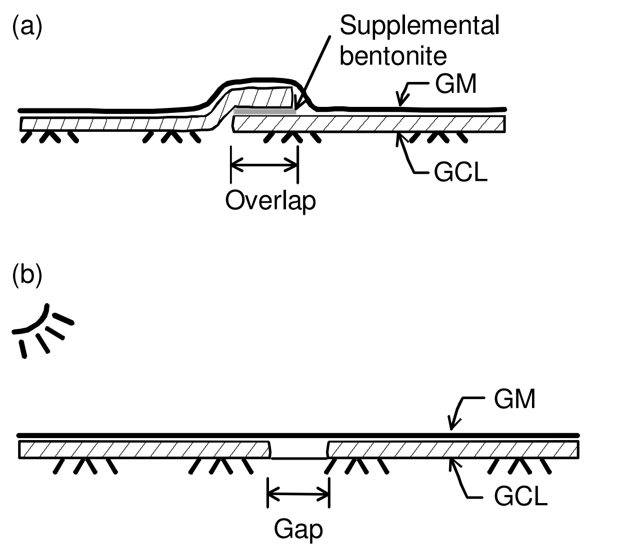

Figure 1. (a) Overlap between geosynthetic clay liner (GCL) panels with supplemental bentonite beneath a geomembrane. (b) Formation of a gap from loss of overlap for an exposed GM/GCL composite liner.

1.2 Overlaps and Supplemental Bentonite

GCLs arrive on-site in rolls that are between 4 to 5 m wide. They are unrolled onto the prepared foundation layer. The adjacent panels are usually overlapped (Figure 1a) between 0.15 to 0.3 m depending on the manufacturer, product, engineering application and exposure conditions.

Supplemental bentonite is often placed between the two overlapped GCLs to improve the seal at the seam. For example, Benson et al. (2004) have shown that supplemental bentonite can significantly improve the hydraulic performance of the GCL overlap. They conducted a laboratory hydraulic conductivity test on GCL samples exhumed from a lagoon with and without a supplemental bentonite. Leakage rates from the overlaps with supplemental bentonite were five to eight times less than leakage rates from overlaps without supplemental bentonite.

1.3 GCL Panel Shrinkage

Thiel and Richardson (2005) and Koerner and Koerner (2005a, 2005b) reported on six cases of GCL seams where there had initially been 0.15 m overlaps that had gaps (e.g., see Fig. 1b) ranging from 0.2 m and 1.2 m wide. These GCLs were all beneath a geomembrane and left uncovered between two months and five years.

If these gaps had not been identified before waste was placed over the liner system, contaminant could easily have leaked into the underlying soil through any holes in the geomembrane at these locations or through holes in geomembrane wrinkles that intersected the open seam. It is important to note that in each case, there was no cover material on top of the geomembrane. If left uncovered, the GM/GCL composite liner is subject to more extreme thermal cycles and lower vertical stresses than if buried beneath a minimum recommended 0.3 to 0.9 m of cover material (depending on the GCL manufacturer).

The most likely reason for the opening of the panel overlaps is from shrinkage of the GCL panel from wetting and drying moisture cycles. GCL shrinkage from imposed wetting and drying cycling has been quantified in laboratory tests (Thiel et al. 2006, Bostwick et al. 2010). Studies have been reported to quantify GCL panel overlap stability with field-scale dimensions, when covered by a geomembrane but left exposed and subject to natural thermal cycling (Brachman et al. 2007, Gastner 2009).

1.4 Objective

The objective of this paper is to assess whether any significant resistance to GCL overlap movement can be mobilized because of the presence supplemental bentonite after experiencing a wetting and drying cycle.

2 METHOD

2.1 GCLs Tested

Four different GCL products were tested. Descriptions of the GCLs tested are given in Table 1. The upper and lower geotextiles (GT) are schematically illustrated in Figure 2. All GCLs contained granular sodium bentonite.

Table 1. Description of the GCLs tested.

GCL	Lower geotextile	Upper geotextile	Layer connection
GCL1	Woven slit-film (W)	Nonwoven staple-fibre needle-punched (NW)	Needle-punched, thermally treated
GCL2	Woven slit-film GT needle-punched to a nonwoven staple-fibre needle-punched GT (W/NW)	Nonwoven staple-fibre needle-punched (NW)	Needle-punched, thermally treated
GCL3	Nonwoven staple-fibre needle-punched (NW)	Woven slit-film (W)	Needle-punched
GCL4	Nonwoven staple-fibre needle-punched (NW)	Nonwoven staple-fibre needle-punched (NW)	Needle-punched

All GCLs, were needle-punched to improve the mechanical bond between the layers. GCLs 1 and 2 were also thermally treated – a process where the needle-punched fibres from the upper geotextile were thermally fused to the bottom side of the lower geotextile. GCLs 3 and 4 were not thermally treated. In the case of GCL 3, the needle-punched fibres from the lower nonwoven geotextile protruded above the upper woven geotextile, whereas they were intertwined with the nonwoven geotextiles for GCL4.

2.2 Procedure

The adhesion was measured over a 100-mm-wide by 100-mm-long overlap zone that had supplemental bentonite after being exposed to one wetting and drying cycle. The procedure followed to prepare the GCL overlap specimens prior to testing is illustrated in Figure 3. First, two GCL specimens 100-mm-wide by 200-mm-long were cut from a virgin GCL roll.

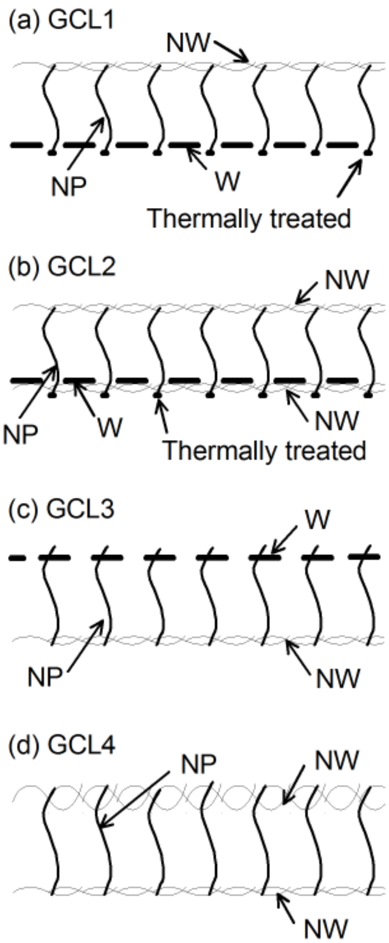

Figure 2. Illustration of upper and lower geotextiles, needle-punched fibres and thermal treatment of the four GCLs tested. NW = nonwoven, W = woven, NP = needle-punched fibre.

The bottom GCL was placed on a clean smooth tray. Next, 26.7 g of bentonite powder which was ground from bentonite extracted from a virgin GCL specimen was uniformly applied in the 100 mm by 100 mm overlap region of the bottom GCL. This is equivalent to a commonly specified field application rate of 0.4 kg/m for a 0.15-m edge overlap. Next, 25 grams of water was applied to the seam to produce a uniformly hydrated bentonite at the overlap region.

Each overlap was then allowed to hydrate at room temperature (22°C) for 24 hours under a confining stress of approximately 3 kPa. The confining stress was removed and finally, the GCL overlap specimen was oven-dried at a temperature of 70°C for 24 hours.

Following sample preparation, each overlap specimen was subjected to tensile force as shown in Figures 4 and 5. Tensile force was applied at a constant rate of extension of 300 mm/min, similar to the rate specified for GCL peel test (ASTM D6496). Since tested at zero normal stress, the peak tensile force provides an assessment of the in-plane adhesion developed from the supplemental bentonite placed at the GCL overlap.

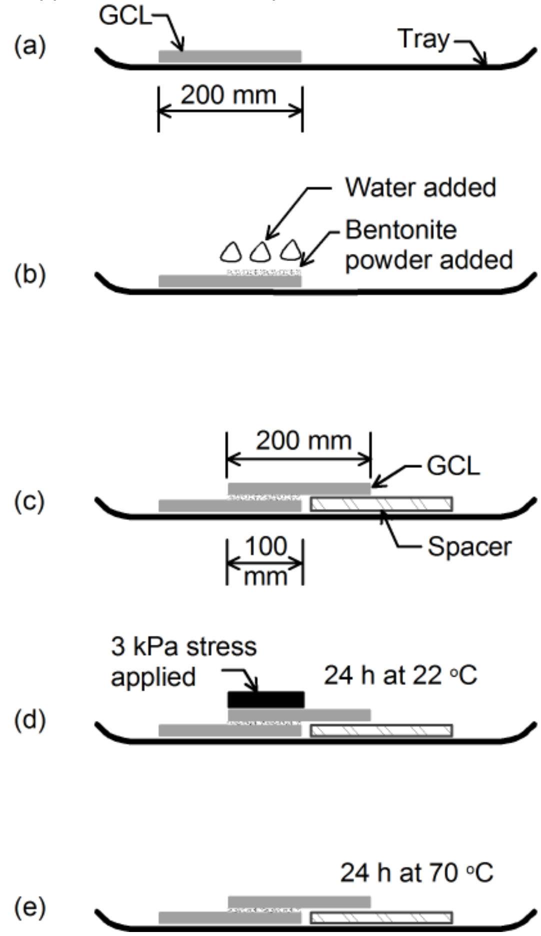

Figure 3. Illustrating of the steps followed in preparing the GCL overlap specimens.

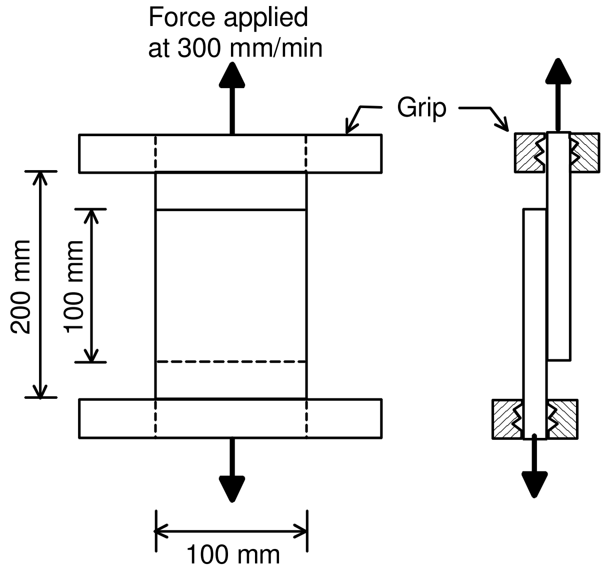

Figure 4. Tensile testing of GCL overlap with supplemental bentonite after one wetting and drying cycle.


Figure 5. Photograph of GCL overlap sample in prior to the start of a test.

3 RESULTS

Figure 6 shows the measured force versus the prescribed displacement for the four GCL overlaps tested. Three replicate tests were conducted for each GCL. In each case, tensile force was mobilized as the displacement increased and reached a peak force prior to pulling the GCL overlap apart. A summary of the peak tensile force is given in Table 2.

The largest tensile force on average was measured for GCL4. Of the products tested, the supplemental bentonite was more effectively anchored by the staple fibres of both the upper geotextile of the bottom piece of GCL4 and the lower geotextile of the top piece of GCL4 after being hydrated and then dried.

The tensile force for GCL2 was approximately 10% less than that for GCL4. Although both staple-fibre nonwoven needle-punched geotextiles, the upper geotextile of the bottom piece of GCL2 was not as thick and had a slightly denser packing of fibres relative to GCL4. Also, thermal treatment of the lower geotextile of the top piece of GCL2 reduced the visible number of protruding fibres. The combined effects of these two surfaces of GCL2 was slightly less effective bonding with the supplemental bentonite and a slightly lower resistance than GCL4.

GCL3 produced interesting results. One would intuitively expect a preferential shear plane if there was truly a smooth, slit film geotextile in contact with bentonite, and thus low tensile resistance. However, the upper woven surface of the bottom piece of GCL3 actually appears to be more like a nonwoven surface because the needle-punched fibres from the lower nonwoven geotextile protruded above the upper woven geotextile. The result was a tensile force on average nearly the same as GCL 2.

Overall, the peak force for GCL2, GCL3 and GCL4 were similar. The differences between their means in Table 2 are not statistically significant (at a 95% confidence interval). This was expected since all had staple fibres protruding from both the upper and lower surfaces.

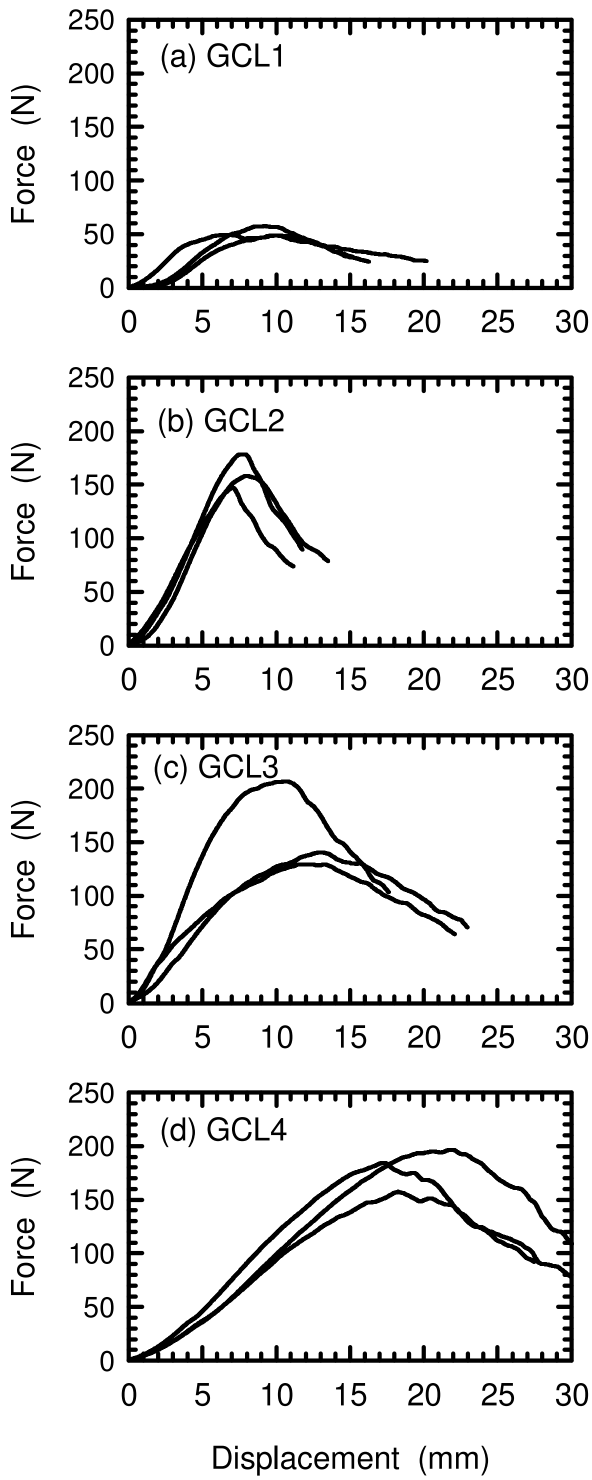

Figure 6. Force-displacement results for overlapped GCL specimens.

The lowest tensile force was mobilized for the overlap for GCL1. Here, just like GCL3, the needle-puched fibres extended through the woven geotextile; however, they were then thermally fused to the woven geotextile. This produced a surface that was not smooth, but one with essentially no free fibres to anchor the supplemental bentonite. There was a tendency for preferential slip between the supplemental bentonite and the lower geotextile of the top piece of GCL1 with the result of one-third of the resistance measured for GCL2, as shown in Figure 7. The adhesion for this GCL was statistically different from that of the other three GCLs, at a 95% confidence interval.

The results for GCLs 1, 2 and 4 showed good repeatability with a coefficient of variation of around 10% between replicate tests. Two of the replicate tests for GCL3 matched well, but one test on GCL3 also produced the largest peak force out of all of the individual tests conducted. In this one test, the large resistance was attributed to a greater than unusual number of need-punched fibres protruding into the overlap.

Table 2. Peak tensile force (N) measured across 100 mm x 100 mm GCL overlap with supplemental bentonite after one wetting and drying cycle.

GCL	Average	Std Dev.	Minimum
GCL1	52	5	49
GCL2	161	16	147
GCL3	158	42	129
GCL4	180	20	157

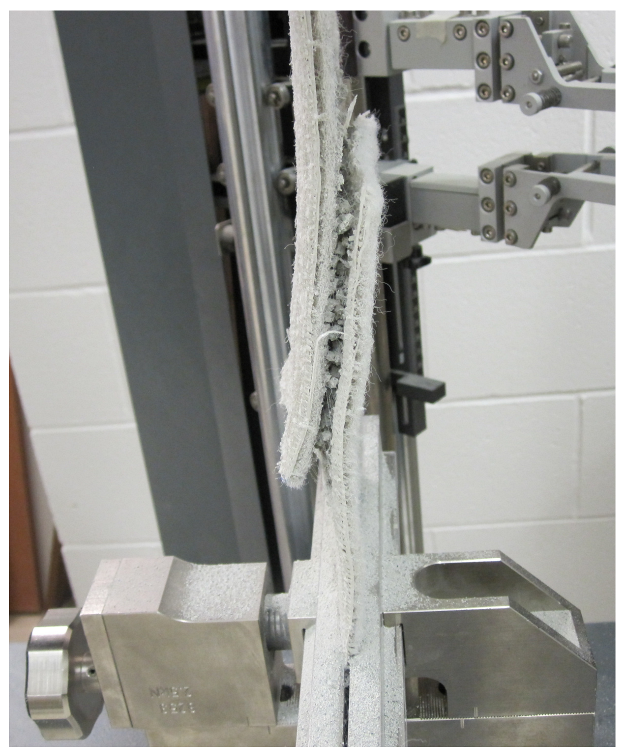

Figure 7. Photograph showing GCL1 overlap sample after a test.

4 SUMMARY

Results were presented from a new index test that showed in-plane shearing resistance (i.e. adhesion) was developed between four different overlapped GCL seams with supplemental bentonite after being exposed to one wetting and drying cycle. The measured adhesion was a function of the texture of either the upper and lower geotextiles of the GCLs. On average, the highest force was measured for the overlap between nonwoven needle-punched geotextiles that were not thermally treated as the hydrated and then dried supplemental bentonite was more able to anchor between staple fibres of the geotextiles. However there was no statistically significant difference between the adhesion observed for there of the GCLs. The lowest adhesion was measured for an overlap that involved a slit-film woven geotextile where the needle-punched fibres from the GCL were thermally melted to the woven geotextile which produced an interface that was less effective in bonding with the supplemental bentonite. The adhesion for this GCL was statistically different from that of the other three GCLs.

While the supplemental bentonite provided some resistance to opening of GCL overlap after one wetting and drying cycle, given the likely variabilities of mass of supplemental bentonite and bentonite hydration, and the unknown demand caused by GCL shrinkage, this adhesion should not be relied upon to provide integrity of GCL overlaps when left exposed; however, the results may be helpful to explain some field observations of GCL overlap movement.

ACKNOWLEDGEMENTS

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