DISPELLING COMMON MYTHS REGARDING GCLs

MYTH #1: POWDERED BENTONITE PROVIDES BETTER HYDRAULIC PERFORMANCE THAN GRANULAR BENTONITE

TRUTH: Assuming similar bentonite quality, powdered or granular particles will exhibit similar hydraulic properties. Depending on the type of initial physical processing (milling vs. screening) performed on mined bentonite ore, either powdered or granular bentonite can be used to manufacture GCLs. The individual bentonite platelets (approximately 1 nm thick and 0.2 to 2 microns in length) are the same in both materials. Powdered bentonite is used by some for its manufacturing benefits, easy availability, and cost effectiveness, not any commercial benefits. Bentomat is manufactured with granular bentonite. The relative hydraulic properties of the grain sizes were evaluated by performing two sets of swell index tests (ASTM D5890) on one bentonite sample: one set of tests was performed on granular clay, while the second set of tests was performed on the same clay, ground into a powder. The results, which are summarized below, show that granular bentonite exhibited similar, or higher swelling behavior than powdered bentonite:

Sample	Swell Index (mL/2g)
Granular (as-received) bentonite	29.5
Granular (as-received) bentonite	29
Granular (as-received) bentonite	29
Powdered (fine ground) bentonite	26
Powdered (fine ground) bentonite	26
Powdered (fine ground) bentonite	25.5

Source: American Colloid Company internal testing (2002)

In theory, powdered bentonite would be expected to be more susceptible to contaminated liquids in the short-term. Ion exchange reactions in bentonite are believed to be diffusion-limited; a finer particle size exposes a larger surface area, thus allowing potentially harmful constituents dissolved in the water to reach the exchange sites faster. Long-term chemical compatibility of granular and powdered bentonites (assuming equal bentonite quality) is expected to be similar.

In practice, the use of GCLs with granular bentonite provides several benefits over GCLs with powdered bentonite. Granular bentonite is contained within the geotextiles of Bentomat and therefore does not escape during handling and installation activities. The powdered bentonite is easily displaced, both laterally within the product and through the geotextiles. Photograph #1 shows a deployment of a GCL roll, where the powder escaping from the liner has generated a cloud of bentonite. Escaped powder bentonite is at best a nuisance and at worst a health hazard. Powder bentonite will also contaminate the welded seams of geomembranes and therefore must be diligently removed prior to seaming, at risk of failing geomembrane QC tests. Powder bentonite is not adequately contained within the geotextiles of a GCL and therefore can escape, decreasing barrier performance and potentially clogging an underlying drainage layer. Powder bentonite is considered a respiratory hazard due to respirable crystalline quartz. Finally, the movement of the powder within the GCL causes localized inconsistencies in the mass per unit area of the product, which in turn creates variability in hydraulic performance.

MYTH #2: TENSILE STRENGTH AND ELONGATION ARE IMPORTANT GCL PERFORMANCE PROPERTIES

TRUTH: The importance of tensile strength and elongation of liner components is often exaggerated. GCLs (regardless of the type and weight of geotextiles used), are first and foremost hydraulic barriers, and should not be relied upon for significant tensile reinforcement within liner systems. When working with hydraulic barriers, such as geomembranes and GCLs, many experienced engineers design using frictional forces alone to maintain slope stability. Past case studies show that in waste failures, the forces generated by sliding waste masses are far higher than any geomembrane or GCL tensile capacity. Professor Timothy Stark of the University of Illinois described the tensile contribution of geosynthetics in landfill liner applications as “tissue paper” (Stark, 2007). Accordingly, when designing with liners, shear strength is a far more important consideration than tensile strength.

Realistically, the importance of tensile strength should be limited to discussions of construction durability. GCLs, such as Bentomat, have been thoroughly tested in a variety of installation configurations and have been subjected to almost every realistic loading scenario imaginable. Bentomat has repeatedly been shown to provide excellent strength characteristics and has been successfully used in extreme conditions. Construction durability data for Bentomat is provided by Fox et. al. (1998).

Elongation has been discussed for cover applications where differential settlement is expected. Based on past experience and literature references (LaGatta, 1992), design engineers can expect differential settlements of approximately 6% in typical municipal solid waste landfill capping applications. Standard needlepunch reinforced GCLs, regardless of manufacturer or geotextile type, have been shown to maintain low hydraulic conductivity in laboratory tests simulating tensile strains between 5 and 16% (LaGatta, 1992). Overlap seams were also tested, and were shown to begin slipping apart at 15% tensile strain. In cases where higher differential settlement is expected, overlaps can be increased accordingly.

Koerner et. al. (1996) evaluated the out-of-plane tensile behavior of GCLs. They noted that geotextile-encased GCLs physically ruptured at strains ranging from 10 to 22%, indicating that permeability breakthrough occurred before the geotextile components ruptured. From inference, it appears that as tensile strains exceed 10 to 15 percent, the GCL area increases excessively, and the bentonite mass per unit area decreases, resulting in increased permeability. Even if a GCL is constructed with stronger or more elastic geotextiles, allowing rupture to occur at tensile strains as high as 100%, the bentonite mass per area (and therefore, the GCL’s usefulness as a hydraulic barrier) will be lost long before that point. When evaluating different GCLs, higher grab elongation does not provide better performance. In part because of these reasons, the elongation test is no longer an industry standard for GCLs. Since 2004, the industry standard for tensile testing of GCLs has been ASTM D6768, which does not include elongation.

MYTH #3: PEEL STRENGTH IS NOT AN IMPORTANT GCL PROPERTY

TRUTH: Peel strength provides a measure of the number and strength of needlepunched connections holding the two geotextiles together, and as such, is an indicator of GCL internal shear strength. A recent municipal solid waste landfill project in the southeastern United States provided a valuable opportunity for comparing peel strength and GCL internal shear strength. Several internal shear strength tests were performed on Bentomat ST at a 240 kPa normal load. The peak internal shear data results were the plotted against peel strength values for each sample. As shown in Figure 2, there was a clear correlation between Bentomat peel strength and hydrated internal shear strength.

Some manufacturers do not provide peel strength values, suggesting that they have difficulty controlling this important manufacturing quality control parameter. This appears particularly true for roll edges that have been impregnated with supplemental bentonite to facilitate seaming. The increased bentonite mass at the edges appears to be making needlepunching more difficult. In addition, the increased bentonite may be lubricating the needlepunched fibers, significantly reducing peel strength in these areas.

Without peel strength data, it is not possible to ensure that adequate internal shear strength will be consistently achieved in the field. Instead, some manufacturers provide “typical” internal shear strength values, obtained through periodic testing – not enough information to guarantee consistency in the field. Since internal shear strength tests are costly and time-consuming efforts, peel strength is a valuable surrogate test that can be performed quickly and frequently. Peel strength testing of Bentomat is performed every 10 to 20 rolls. CETCO certifies Bentomat to a minimum peel strength of 400 N/m, and can produce special orders with higher peel values for individual projects with stringent shear strength requirements. Bentomat DN is the GCL used in canyon landfills in the western U.S., some of the most demanding applications encountered anywhere, which involve slopes as steep as 1.5H:1V, and waste masses almost a hundred meters high.

MYTH #4: THE METHYLENE BLUE TEST CAN BE USED TO IDENTIFY HIGH-QUALITY, HIGH-PERFORMING SODIUM BENTONITE

TRUTH: The methylene blue test is a titration test which gives an approximation of a soil’s cation exchange capacity (CEC), not its montmorillonite content, nor its hydraulic performance. The CEC of a soil is measured in units of meq/100 g and has no defined relationship to montmorillonite content or to GCL hydraulic performance. The methylene blue method assumes that pure montmorillonite has a CEC of 100 meq/100 g; however, montmorillonites can have CEC values as high as 140 meq/100 g, or as low as 70 meq/100 g. Regardless, hydraulic performance is independent of the CEC value, so both samples could pass the montmorillonite requirement, without a guarantee that they would meet hydraulic performance requirements.

For these reasons, the industry does not consider methylene blue or CEC tests appropriate for GCLs. Instead, free swell (ASTM D5890), fluid loss (ASTM D5891), and index flux (ASTM D5887) tests are used to distinguish between low-quality and high-quality bentonites. The intent of the fluid loss and free swell tests is to ensure that the raw material is a high-quality sodium bentonite, that will consistently yield a GCL hydraulic conductivity less than or equal to 5×10^{-9} cm/sec. The threshold values of 24 mL/2g free swell and 18 mL fluid loss are not arbitrary numbers – they have been set based on years of data to ensure passing permeability results.

MYTH #5: BENTONITE MOISTURE CONTENT IN GCLs SHOULD BE LIMITED TO LESS THAN 20%.

TRUTH: For bentonite moisture contents below 40%, concerns over bentonite displacement and squeeze-out are not warranted because the bentonite still retains a granular appearance, consistency, and strength. Due to differences in the respective manufacturing processes, some manufacturers produce GCL with a lower bentonite moisture content (15%) than Bentomat (<30%). As part of the Bentomat manufacturing process, water is added to the bentonite to improve needlepunching, resulting in greater GCL peel strength and internal shear strength. Some have implied that slightly higher moisture of Bentomat will result in bentonite displacement and squeeze-out. The slightly higher bentonite moisture is still below fully hydrated bentonite, and will have no negative effect on GCL performance or installation whatsoever. Figure 3 from Daniel and Stark (2000) shows that the internal friction angle of bentonite with 35% to 40% moisture is very high (39 degrees), comparable to a coarse-grained soil that can withstand shear stresses and point loads. It is only when moisture exceeds 50% to 100%, that the clay will begin to hydrate and swell, forming a viscous, homogeneous mass, that no longer appears granular (depending on the confining pressure, bentonite given free access to water could attain moisture contents in excess of 200%).

MYTH #6: THERMAL LOCKING IS NECESSARY TO ACHIEVE HIGH INTERNAL SHEAR STRENGTH

TRUTH: Different manufacturers employ different methods of increasing GCL internal reinforcement. Bentomat is manufactured using a needlepunching process, where fibers from the nonwoven geotextile cover are driven through the bentonite layer and then several centimeters past the bottom geotextile. This manufacturing technique provides a high degree of internal reinforcement and resistance to thread pull-out, allowing Bentomat to meet project requirements for peel strength and internal shear strength, without the need for any supplemental thermal treatment. Other manufacturers use a similar needlepunch process, except at significantly lower needlepunch density, which is partially offset by applying a thermal bonding process. When heat is applied to the needlepunched polypropylene fibers, they melt into small "pills" on the surface of the encapsulating geotextile.

As shown in Figure 4, the needle-punching process used to produce Bentomat is expected to provide improved shear strength over GCLs manufactured with thermal locking. Researchers at the University of Colorado and University of Texas at Austin recently completed a comprehensive study in which a large database of internal GCL shear tests was arranged and analyzed by GCL type. The results of their study, summarized in the attached technical reference, found that needle-punched GCLs without thermal locking (GCL-A, Bentomat ST) have higher peak shear strengths than GCLs with thermal locking (GCL-C). GCL-A appears to have a 4 to 5-degree advantage over GCL-C (33.5 degrees vs. 28.9 degrees). Based on these comparisons, the study concluded that, "**..thermal locking did not lead to the expected increase in shear strength**." Additional evidence of this difference in peak strength has also been observed during project-specific interface shear test involving GCLs placed against other geosynthetics. Case studies are available upon request.

REFERENCES

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2. Fox, P.J., Triplett, E.J., Kim, R.H., and Olsta, J.T. (1998). "Field Study of Installation Damage for GCLs," Geosynthetics International, vol. 5, no. 5, pp. 491-520.
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4. Koerner, R.M., Koerner, G.R., and Eberle, M.A. (1996). "Out-of-Plane Tensile Behavior of GCLs," Geosynthetics International, vol. 3, no. 2, pp. 277-296.
5. McCartney, J.S., Zornberg, J.G., and R.H. Swan (2002), "Internal and Interface Shear Strength of Geosynthetic Clay Liners (GCLs)," University of Colorado at Boulder.
6. Stark, T.D. (2007). "GCL Shear Strength and Slope Stability". Presented at GCL University, Philadelphia, Pennsylvania.

FIGURE 1 – LOSS OF POWDERED BENTONITE DURING GCL DEPLOYMENT

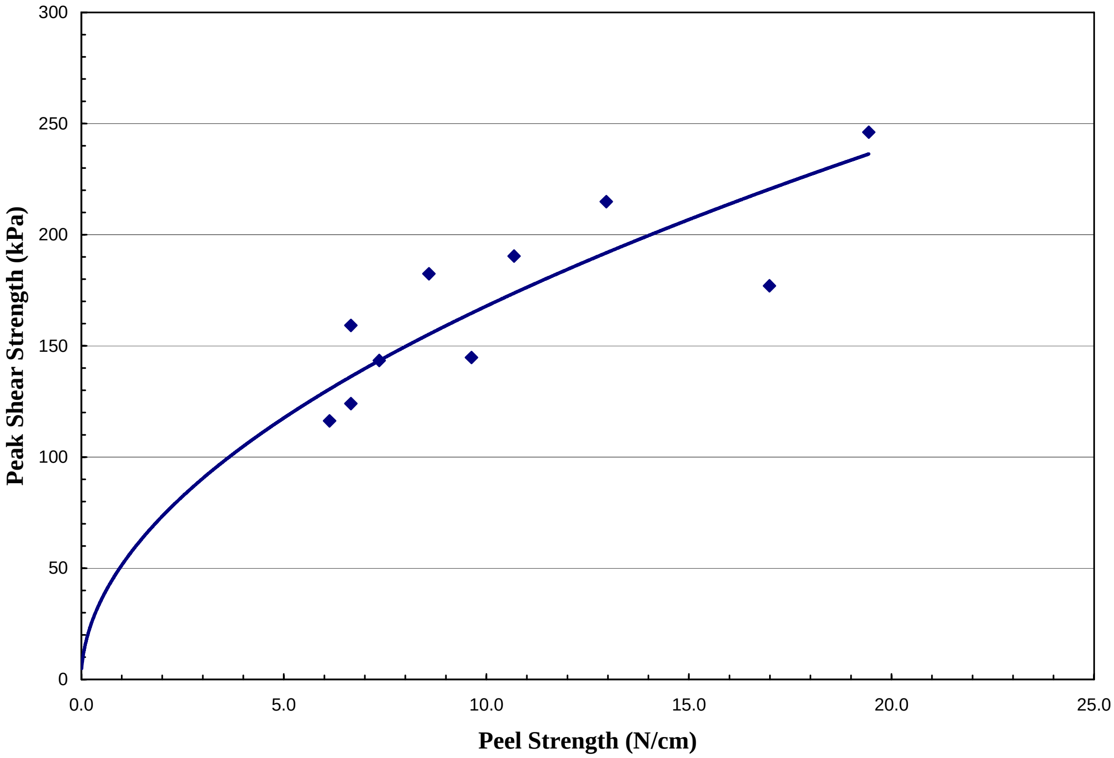

FIGURE 2 – PEEL STRENGTH VS. GCL INTERNAL SHEAR STRENGTH
Source: Confidential Bentomat ST project with Major U.S. Waste Company, 2006

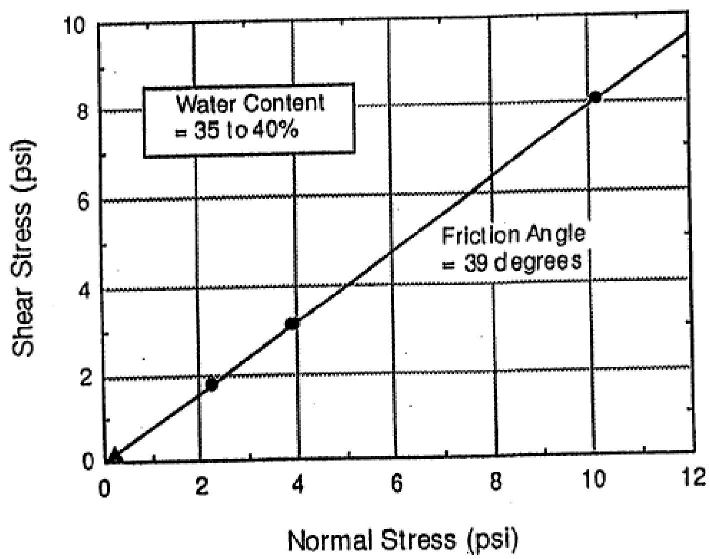

FIGURE 3 – BENTONITE SHEAR STRENGTH AT 35 - 40% MOISTURE CONTENT
Source: Daniel and Stark (2000), Course Notes from "GCLs for Containment of Wastes, Chemicals, and Liquids". University of Illinois at Urbana-Champaign.

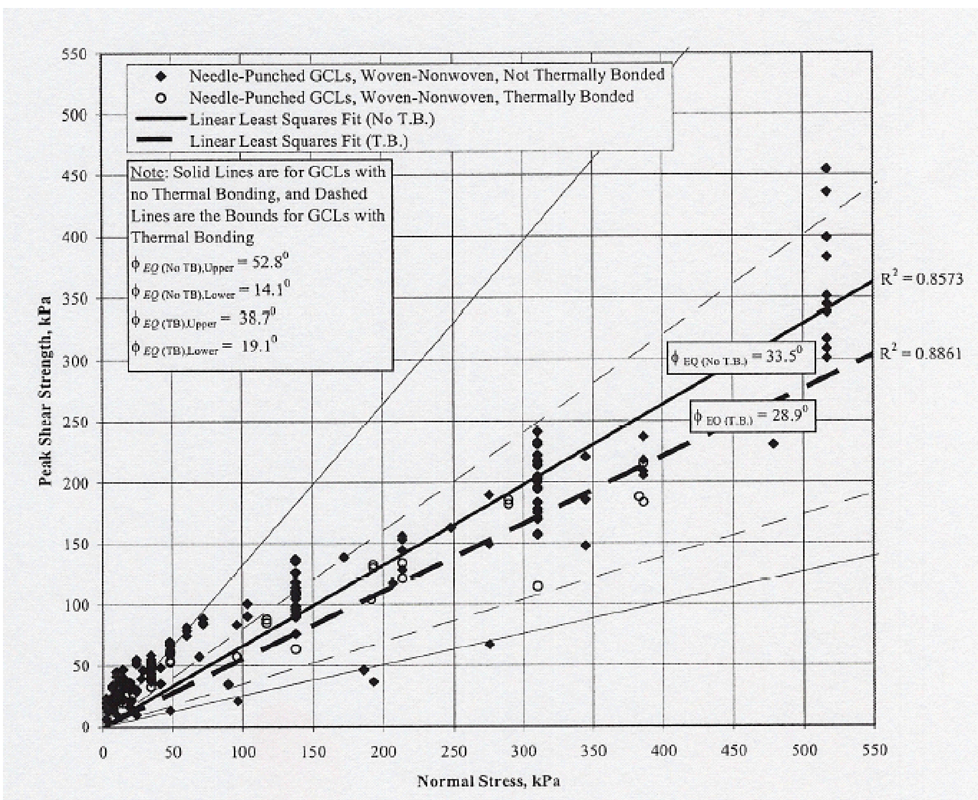

FIGURE 4 – COMPARISON OF GCL INTERNAL SHEAR STRENGTH
Source: McCartney, J.S. et. al. (2002), "Internal and Interface Shear Strength of GCLs," University of Colorado at Boulder.