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## Technical Equivalency of GSE GundSeal GCL to Compacted Clay Liner (1 of 2)



GSE GundSeal geomembrane supported GCL.

Since their introduction in 1986 as barrier systems for waste containment sites, geosynthetic clay liners (GCLs) have been installed in a wide variety of landfill, wastewater treatment, and secondary containment systems. With the increasing interest in the use of GCLs as part of a liner system, both state and federal regulatory agencies have been questioned by facility owners, operators, and design consultants as to the position of these agencies on the use of GCLs in waste containment systems.

Often, the standard answer received by the design engineer or owner and operator is that they must show that the GCL is equal to

a specified thickness of compacted clay liner (CCL). A review of both compacted clays and GCLs reveals that they are quite different by construction and can not be equal. In other words, a 4 mm (0.2 in) GCL bentonite layer is not equal to two feet of clay. However, the hydraulic performance of a GCL can be considered equivalent to the performance of a clay liner given the proper installation and manufacturing quality assurance (MQA) and construction quality assurance (CQA).

Koerner and Daniel (1993)<sup>2</sup> and Daniel (1993)<sup>1</sup> present data regarding an equivalent assessment of GCLs compared to CCLs. Table I presents the 22 critical equivalency issues presented in Koerner and Daniel's paper. As indicated in the table, there are three major categories involved in comparing compacted clay liners and geosynthetic clay liners. These categories are (1) hydraulic issues, (2) physical and mechanical issues, and (3) construction issues. Table II presents the technical equivalency assessment for GSE GundSeal installed as a composite liner (geomembrane and clay) in landfill and surface impoundment liner systems. Note that there are only two areas where GSE GundSeal is probably not equivalent to a CCL. These areas include chemical absorption capacity as a hydraulic issue and puncture resistance as a construction issue.

Equivalency to compacted clay cannot be demonstrated for GCLs with regard to chemical absorption capacity and diffusion. However, this question is mute if a geomembrane and geosynthetic clay liner composite liner system has been properly installed. The absorption by GSE GundSeal may be adequate to very low water flux. In the long term, the absorption capacity for all liners (including CCLs) may eventually be exhausted. If the composite is the primary liner of a double liner system, the leak detection system will manage the liquid build-up on the lining system, and absorption is not relevant. Therefore, only when a GCL is used by itself without a protective overlying geomembrane can real concern be expressed for chemical absorption capacity. Even then, site specific conditions will be very important. Given the geomembrane backing of GSE GundSeal, the issue of chemical absorption is negligible.

The puncture resistance of 600 mm (2 ft) of compacted clay is obviously much higher than the puncture resistance of a thin GCL. However, careful CQC and CQA procedures are able to address the potential puncture problem. As noted in Table II, the advantages of GCLs over compacted clay offset its vulnerability to puncture.

### GSE GUNDSEAL SHEAR STRENGTH SUMMARY

In Appendix 1, water flux calculations have been prepared for the bentonite component of GSE GundSeal and a corresponding 600 mm (2 ft) compacted clay liner. From these calculations, it is evident that GSE GundSeal geosynthetic clay liner out performs a compacted clay liner. This type of analysis and comparison can be performed for all items listed in Table I. A detailed discussion is presented by Koerner and Daniel (1993) for all of these items.

#### References:

- <sup>1</sup>Daniel D.E. (1993) "Geosynthetic Clay Liners (GCLs) in Landfill Covers." Proc. SWANA Conf., San Jose, CA.  
<sup>2</sup>Koerner, R.M. and Daniel, D.E. (1993) "Technical Equivalency Assessment of GCLs to CCLs."  
"Proc. Seventh Annual GRI Seminar, Geosynthetic Research Institute, Philadelphia, PA."

**APPENDIX 1**

*Water Flux Calculations*

Water flux is defined as the volume of flow across a unit area in a unit time. The steady downward flux of water ( $v$ ) through an individual layer of porous material with zero water pressure at the base of the layer is defined from Darcy's law as:

$$V = \frac{KH+T}{T} \quad \text{where}$$

$K$  = hydraulic conductivity of material

$H$  = depth of liquid ponded on the liner

$T$  = thickness of the liner

The above equation is valid for flow through the bentonite component of GSE GundSeal. Since GSE GundSeal contains a geomembrane, water flux is controlled by water vapor diffusion through the geomembrane backing.

However, in performing an equivalency analysis to compacted clay and in computation of water flux, the geomembrane backing should be considered by the design engineer. The simplest way to perform this analysis is to adjust the hydraulic conductivity of GSE GundSeal to include the geomembrane. This simplification is not indicative of the actual flow considerations since water flows through a geomembrane by diffusion and Darcy's law does not apply to diffusion. However, by making this simplifying assumption, an engineer can obtain an estimate of water flux for GSE GundSeal.

The water flux equation applies to GSE GundSeal or a compacted clay liner alone and does not apply to composite liners involving one or more separate geomembrane components. For GSE GundSeal the water flux for a site where  $H = 1'$  (30.48 cm) is calculated as follows:

$$K = 4 \times 10^{-12} \text{ cm/sec}, T = 1/6'' = 0.4233 \text{ cm}$$

$$V_{GCL} = (4 \times 10^{-12} \text{ cm/sec}) \times \frac{30.48 \text{ cm} + 0.4233 \text{ cm}}{0.4233 \text{ cm}}$$

$$V_{GCL} = 2.92 \times 10^{-10} \text{ cm/sec}$$

For two (2) feet (60.96 cm) of compacted clay where

$$K = 1 \times 10^{-7} \text{ cm/sec}$$

$$V_{CCL} = (1 \times 10^{-7} \text{ cm/sec}) \times \frac{30.48 \text{ cm} + 60.96 \text{ cm}}{60.96 \text{ cm}}$$

$$V_{CCL} = 1.5 \times 10^{-7} \text{ cm/sec}$$

$$(CCL) \quad F_w = \frac{V_{GCL}}{V_{CCL}} = \frac{2.92 \times 10^{-10} \text{ cm/sec}}{1.5 \times 10^{-7} \text{ cm/sec}} = 1.95 \times 10^{-3}$$

the flux ratio is  $\leq 1$  ( $2.95 \times 10^{-3} \leq 1$ ), then GSE GundSeal is more than equivalent to a CCL in terms of steady water flux.

$$V_{GCL} = V_{GCL}$$

Alternatively, the engineer can assume the water flux ( $V$ ) through a CCL and GSE GundSeal are equal. And, compute the required hydraulic conductivity for GSE GundSeal using the following equation:

$$(K_{GCL})_{req} = K_{CCL} \times \frac{T_{GCL}}{T_{CCL}} \times \frac{H + T_{CCL}}{H + T_{GCL}}$$

For the previous example

$$(K_{GCL})_{req} = (1 \times 10^{-7} \text{ cm/sec}) \times \frac{0.4233 \text{ cm}}{60.96 \text{ cm}} \times \frac{30.48 \text{ cm} + 60.96 \text{ cm}}{30.48 \text{ cm} + 0.4233 \text{ cm}}$$

$$= 2.05 \times 10^{-9} \text{ cm/sec}$$

$$K_{GundSeal} = 4.2 \times 10^{-12} \text{ cm/sec} \leq 2.05 \times 10^{-9}$$

Therefore, using either method, GSE GundSeal is more than equivalent to 600 mm (2 ft) of compacted clay when considering the water flux through a CCL.



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## Technical Equivalency of GSE GundSeal GCL to Compacted Clay Liner (2 of 2)

**TABLE 1<sup>4</sup> - Potential Equivalency Issues for Geosynthetic Clay Liners (GCLs) vs. Compacted Clay Liners (CCLs)**

Category	Criterion for Evaluation	Possibly Liners	Relevant for Covers
Hydraulic Issues	Steady Flux of Water	X	X
	Steady Solute Flux	X	
	Chemical Adsorption Capacity	X	
	Breakout Time:		
	- Water	X	X
	- Solute	X	
	Production of Consolidation Water	X	X
Permeability to Gas	X	X	
Physical/Mechanical Issues	Freeze/Thaw	X <sup>1</sup>	X
	Wet/Dry		X
	Total Settlement	X <sup>2</sup>	X
	Differential Settlement	X <sup>2</sup>	X
	Slope Stability	X <sup>3</sup>	X
	Erosion		X
	Bearing Capacity	X	X
Construction Issues	Puncture Resistance	X	X
	Subgrade Condition	X	X
	Ease of Placement	X	X
	Speed of Construction	X	X
	Availability of Materials	X	X
	Requirements for Water	X	X
	Air Pollution Effects	X	X
	Weather Constraints	X	X
	Quality Assurance	X	X

<sup>1</sup> Relevant only until liner is covered sufficiently to prevent freezing.

<sup>2</sup> Settlement of liners usually of concern only in certain circumstances, e.g., vertical expansion

<sup>3</sup> Stability of liner may not be relevant after filling if no permanent slope remains

<sup>4</sup> Daniel (1993), "Geosynthetic Clay Liners (GCLs) in Landfill Covers", Presented at Thirty First Annual Solid Waste Exposition, Solid Waste Association of North America, San Jose, California, August 2-5, 1993.

**TABLE II<sup>2</sup> - Technical Equivalency Assessment for GSE GundSeal Installed Beneath Geomembranes in Landfills and Surface Impoundments**

Category	Criterion for Evaluation	GSE GundSeal is Superior	GSE GundSeal is Equivalent	GSE GundSeal is probably not Equivalent
Hydraulic Issues	Steady flux of water		X	
	Steady solute flux		X	
	Chemical adsorption capacity			X
	Breakout time			
	- water	X		
	- solute	X		
	Horizontal flow			
	- in seams		X	
- or lifts	X			
Horizontal flow beneath geomembrane				
Generation of consolidation water	X			
Physical/Mechanical Issues	Freeze/thaw behavior	X		
	Total settlement		X	
	Differential settlement	X		
	Slope stability		X <sup>1</sup>	
	Bearing capacity		X <sup>1</sup>	
Construction Issues	Puncture resistance			X
	Subgrade condition		X	
	Ease of placement	X		
	Speed of construction	X		
	Availability of material	X		
	Requirements for water			
	Air pollution concerns	X		
	Weather constraints	X		
	Quality assurance considerations		X	

<sup>1</sup>Equivalent when installed with geomembrane backing facing downward against subgrade soils and covered with another geomembrane.

<sup>2</sup>Table adapted from "Technical Equivalency Assessment of GCLs to CCLs; Koerner and Daniel (1993); Proceedings of the 7th GRI Seminar, Geosynthetic Liners Systems: Innovations, Concerns and Design, Drexel University, Philadelphia, PA, pp 255-275.