Geosyntec
consultants

COMPUTATION COVER SHEET

Client:	**Denison Mines**	Project:	**White Mesa Mill – Cell 4B**	Project/ Proposal No.:	**SC0349**
				Task No.	**03**

Title of Computations **REVISED CUSHION FABRIC CALCULATIONS**

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Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	M. Lithgow	Date:	08/03/09	Reviewed by:	G. Corcoran	Date:	8/7/09
Client:	DMC	Project:	Cell 4B	Project/ Proposal No.:	SC0349	Task No.:	03

REVISED CUSHION FABRIC CALCULATIONS
WHITE MESA MILL – CELL 4B
BLANDING, UTAH

OBJECTIVE

The project involves placement of a double composite liner system for the base of Cell 4B at the White Mesa Mill in Blanding, Utah. The proposed liner system is shown in Attachment A. The objective of this calculation is to evaluate the maximum particle sizes of soil/aggregate materials adjacent to the geomembrane that will not puncture or damage the geomembrane. This calculation package has been revised to reflect the most current updates to the Geosynthetic Institute design standard.

SUMMARY OF ANALYSIS

The analyses suggest that the following maximum particle sizes and geotextile mass per unit areas will be required:

Component of Liner	Maximum Particle Size (in)	Maximum Protrusion Height (in)	*Cushion Material*
Slimes drain system over geomembrane	1.0	N/A	16 oz/yd^2
Leak detection system (LDS) over geomembrane	1.0	N/A	16 oz/yd^2
Geosynthetic clay liner (GCL) over prepared subgrade	N/A	½	3 oz/yd^2 + 6 oz/yd^2

SITE CONDITIONS

The proposed double composite liner system will be comprised of the following components, from top to bottom:

- 60-mil HDPE primary geomembrane;

- Geonet (LDS);
- 60-mil HDPE secondary geomembrane; and
- GCL.

The slimes drain will be placed on top of the primary geomembrane, surrounded with gravel which will then be wrapped in a 16 oz/yd^2 geotextile. The LDS will be installed between the primary geomembrane and the secondary geomembrane, and will consist of a PVC pipe surrounded by aggregate and wrapped in a 16 oz/yd^2 geotextile. The GCL will be installed on the prepared subgrade.

The tailings deposits are anticipated to be similar to silt with an average maximum wet unit weight of 125 pounds per cubic foot (pcf) (See slope stability calculation for this value). For conservatism, we have assumed that a maximum of 42 ft of tailing deposits may be present. Therefore, the design overburden pressure is 42 ft × 125 pcf = 5,250 pounds per square foot (psf) or 251 kilopascals (kPa).

APPROACH

Wilson-Fahmy, Narejo, and Koerner have evaluated puncture protection of geomembranes in a series of four papers. These papers are:

1) Wilson-Fahmy, R.F., Narejo, D., and Koerner, R.M (1996) "Puncture Protection of Geomembranes Part I: Theory", Geosynthetics International, Vol. 3, No. 5, pp. 605-628

2) Narejo, D., Koerner, RM. and Wilson-Fahmy, R.F. (1996) "Puncture Protection of Geomembranes Part II: Experimental", Geosynthetics International, Vol. 3, No. 5, pp. 629-653

3) Koerner, R.M., Wilson-Fahmy, R.F. and Narejo, D. (1996) "Puncture Protection of Geomembranes Part III: Examples," Geosynthetics International, Vol. 3, No. 5, pp. 655-675

4) Koerner, R.M., (2008) "Modification to the "GRI-Method" for the RF_{CR}-Factor Used in the Design of Geotextiles for Puncture Protection of Geomembranes," Geosynthetics International, GRI White Paper #14.

These papers present an evaluation of geomembrane puncture theory, the results of a laboratory experimental program, and design examples in regards to puncture protection of geomembranes. The design methods and conclusions of these four papers were used for the analysis herein.

According to these papers, the important parameters that affect the puncture protection of geomembranes are: overlying pressure, mass per area of the geotextile, and the particle size and shape of the material overlying the geotextile. For the analysis herein, the overlying pressure and the mass per unit area of the geotextile are given and the maximum particle size is evaluated for the two types of geotextile.

ANALYSES

Koerner (2008, Attachment B) present the following equation for evaluating geotextile puncture protection of 60 mil (1.5 mm) HDPE geomembrane:

$$p_{allow} = 50 + \frac{0.000450\text{ M}}{\text{H}^2} \qquad \text{(Attachment B)}$$

where:

H = cone height (mm), which corresponds to predicted effective protrusion height, which equals one-half maximum stone size.

Case I: M = mass per unit area geotextile (g/m^2)

= 16 oz/yd^2 = 542 g/m^2 (slimes drain and LDS)

Case II: M = 9 oz/yd^2 = 305 g/m^2 (GCL overlying prepared subgrade)

P_{allow} = maximum long term allowable pressure

where: $P_{allow} = P'_{allow}\left(MF_S \times MF_{PD} \times MF_A\right)\left(RF_{CBD} \times RF_{CR}\right)$ (Attachment B)

where: MF_S, MF_{PD}, MF_A = modification factors (discussed below)

RF_{CBD}, RF_{CR} = partial factor of safety values (discussed below)

P'_{allow} = allowable pressure based on field conditions (Attachment B)
$= (FS)(P_{actual\ field\ pressure})$

where: FS = global factor of safety, 3.0 (Attachment B)

$P_{actual\ field\ pressure}$ = 251 kPa

P'_{allow} = (251)(3) = 753 kPa

MF_S = shape factor: (Attachment B)
1.0 (assume angular particles)

MF_{PD} = packing density: (Attachment B)
1.0 (assume isolated protrusions)

MF_A = soil arching: (Attachment B)
1.0 (assume none)

RF_{CR} = partial factor of safety for creep: (Attachment B)
for H > 12 mm, FS_{CR} = 1.3

RF_{CBD} = partial factor of safety for chemical and biological degradation: (Attachment B)
1.5 (based on aggressive environment for polypropylene geotextiles in LDS and slimes drain)

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1.0 (GCL on prepared subgrade)

Solving for P_{allow} provides:

Case I: $P_{allow} = (753)\,(1.0 \times 1.0 \times 1.0)\,(1.3 \times 1.5)$

$P_{allow} = 1{,}468$ kPa

Case II: $P_{allow} = (753)\,(1.0 \times 1.0 \times 1.0)\,(1.3 \times 1.0)$

$P_{allow} = 979$ kPa

Solving for H, the predicted effective protrusion height, provides:

Case I:

$$H^2 = \frac{0.00045M}{P_{allow} - 50}$$

$$H_{cushion} = \left(\frac{0.00045(542)}{1{,}468 - 50}\right)^{1/2} = 0.013\text{ m} = 0.5\text{ in}$$

Case II:

$$H_{cushion} = \left(\frac{0.00045(305)}{979 - 50}\right)^{1/2} = 0.012\text{ m} = 0.5\text{ in}$$

The predicted effective protrusion height equals one half the maximum stone size. Therefore, the maximum stone size for the gravel to be placed around the slimes drain and in the LDS is 2 × 0.5 inch, or 1.0 inch.

NOTE TO TECHNICAL SPECIFICATIONS

For practical construction and CQA purposes, the calculated maximum particle sizes and protrusion heights of the soil components of the liner are rounded down to a convenient magnitude. The subgrade will be rolled and compacted; therefore, the maximum protrusion height (instead of maximum particle size) is required for the technical specifications. The specifications should reflect the following information:

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Soil Component of Liner	Maximum Protrusion Height (in.)	Maximum Particle Size (in.)
Drainage aggregate	N/A	1.0
Prepared subgrade	½	N/A

REFERENCES

Koerner, R.M., (2008) "Modification to the "GRI-Method" for the RF_{CR}-Factor Used in the Design of Geotextiles for Puncture Protection of Geomembranes," Geosynthetic Institute, GRI White Paper #14.

Koerner, R.M., Wilson-Fahmy, R.F. and Narejo, D. (1996) "Puncture Protection of Geomembranes Part III: Examples", Geosynthetics International, Vol. 3, No. 5, pp. 655-675.

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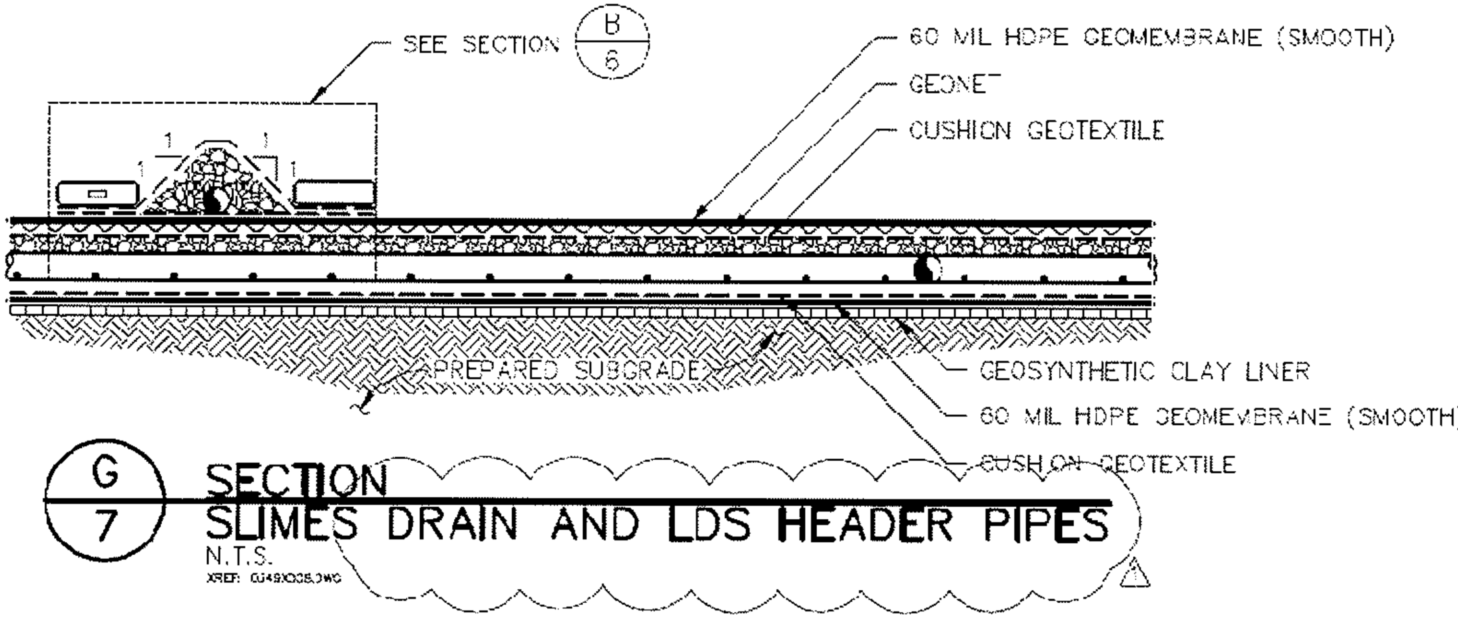
SEE SECTION
B
6
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60 MIL HDPE GEOMEMBRANE (SMOOTH)
GEONET
CUSHION GEOTEXTILE
PREPARED SUBGRADE
GEOSYNTHETIC CLAY LINER
60 MIL HDPE GEOMEMBRANE (SMOOTH)
CUSHION GEOTEXTILE
G
7
SECTION
SLIMES DRAIN AND LDS HEADER PIPES
N.T.S.

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GRI GEI GII GSI GAI GCI

GRI White Paper #14

Modification to the "GRI-Method" for the RF_{CR}-Factor Used in the Design of Geotextiles for Puncture Protection of Geomembranes

by

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Attachment B, 1/3

While many theses and technical papers have been written using this experimental test setup, a series of three papers captures the entire program; Wilson-Fahmy, et al. (1997), Narejo, et al. (1997) and Koerner, et al. (1997). The resulting design formula uses a conventional factor of safety as follows:

$$FS = p_{allow} / p_{act} \tag{1}$$

where

- FS = factor of safety (against geomembrane puncture),
- p_{act} = actual pressure due to the applied normal stress, e.g., landfill contents or surface impoundments, and
- p_{allow} = allowable pressure using different types of geotextiles and site-specific conditions

Based on the experimental test results an empirical relationship for "p_{allow}" was obtained. It is given as Equation 2. Its use, however, requires the use of modification factors and reduction factors as given in Table 1. Note that in this table, all MF values ≤ 1.0 and all RF values ≥ 1.0.

$$p_{allow} = \left(50 + 0.00045\frac{M}{H^2}\right)\left[\frac{1}{MF_s \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CBD} \times RF_{CR}}\right] \tag{2}$$

where

- p_{allow} = allowable pressure (kPa),
- M = geotextile mass per unit area (g/m^2),
- H = protrusion height (m),
- MF_S = modification factor for protrusion shape,
- MF_{PD} = modification factor for packing density,
- MF_A = modification factor for arching in solids,
- RF_{CBD} = reduction factor for long-term chemical/biological degradation, and
- RF_{CR} = reduction factor for long-term creep.

Attachment B, 2/3

Table 1. Modification factors and reduction factors for geotextile protection material design using Equation 2, i.e., the "GRI-Method".

(a) Modification factors (all ≤ 1.0)

MF_s		MF_{PD}		MF_A	
Angular	1.0	Isolated	1.0	Hydrostatic	1.0
Subrounded	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.50
		Dense, 12 mm	0.50	Geostatic, deep	0.25

(b) Reduction factors (all ≥ 1.0)

RF_{CBD}		RF_{CR} Mass per unit area (gm/m^2)	Protrusion height (mm) 38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3	270	N/R	N/R	>1.5
* Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		>1100	≅ 1.2	≅ 1.1	≅ 1.0

Abbreviation: N/R = Not recommended

The design situation can be approached by using a given mass per unit area geotextile to determine the unknown FS-value, or from using a given FS-value to determine the unknown mass per unit area geotextile. Koerner (2005) gives numeric examples, and Valero and Austin (1999) present design charts for the many variables contained in the design equation. It might be noted that this method is the only design method that allows for direct selection of a geotextile protection material without the need for large scale trail-and-error experimental testing.

In Equation 2 the two terms "RF_{CBD}" and "RF_{CR}" are intended to extend the short term test results into a simulated long term performance behavior. Since HDPE is quite resistant to chemical and biological degradation, the term RF_{CBD} is comparatively small. The term RF_{CR}, however, is not small and in many cases a "not recommended" decision is suggested. Due to its importance in the overall design, a series of long term creep tests using this same methodology,

Attachment B, 3/3