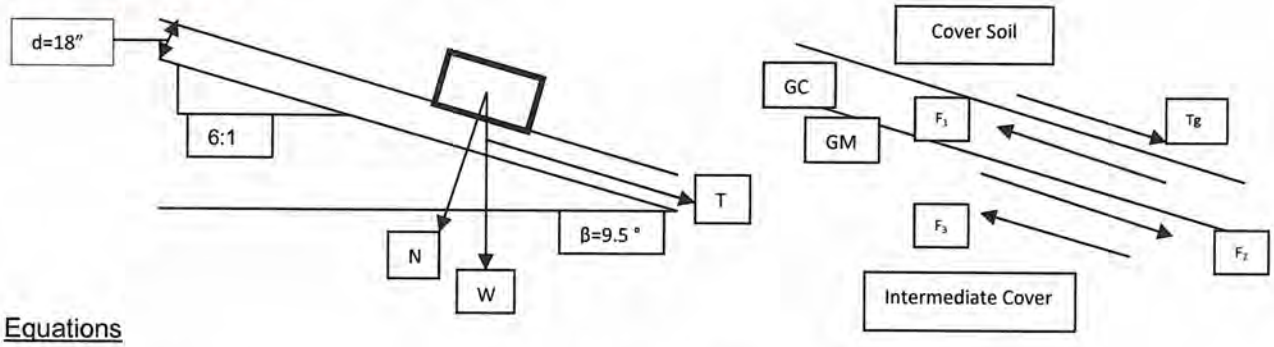
CALCULATIONS

Date:	September 3, 2013	**Made by:**	DPM
Project No.:	130-0193	**Checked by:**	KAL
Subject:	Stress on Liner during Construction Final Grades	**Reviewed by:**	JRD
Project:	CEC Ash Landfill – SWP #440		

1.0 OBJECTIVE

To determine the minimum factor of safety of stress on the liner during construction. A D6LGP dozer on 18" cover soil layer will be used in calculation.

2.0 METHOD



Equations

$P_c = WnT_wT_l$ — Where P_c = Contact Pressure; W= Weight of Equipment; T_w= Track Width; T_l= Track Length; n= Number of Tracks

$N = P_c cos\beta$ — Where N= Normal Force; P_c = Contact Pressure; β= Slope Angle

$T = P_c sin\beta$ — Where T= Tension Force in Geocomposite (GC)

$N_g = N + \gamma_{soil} d cos\beta$ — Where N_g= Normal Force on Geocomposite (GC); γ_{soil}= Unit Weight of Cover Soil; d= Depth of Cover Soil

$T_g = T + \gamma_{soil} d sin\beta$ — Where T_g= Sliding Force on Geocomposite (GC)

$F_1 = N_g tan\delta_1$ — Where F_1= Sliding Resistance on Geocomposite (GC); δ_1= Geocomposite/Drainage Soil Interface Friction Angle

$F_2 = T_g$ — Where F_2= Sliding Resistance in Geomembrane/Geocomposite (GM)

$F_3 = N_g tan\delta_3$ — Where F_3= Sliding Resistance on Geomembrane (GM); δ_3= Geomembrane/Intermediate Cover Interface Friction Angle

$FS = {F_{1,3}}/{T_g}$ — Where FS= Factor of Safety

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3.0 ASSUMPTIONS

1. A D6LGP dozer is used or equipment of less than or equal weight.
2. A 40 mil HDPE textured is used as the geomembrane.
3. The interface friction angle of the geocomposite to cover soil is 30 degrees.
4. The interface friction angle of the geomembrane to intermediate cover is 29.0 degrees.

4.0 CALCULATIONS

Where;

W=	weight of equipment	=	44,823	lb
T_w=	track width	=	3	ft
T_l=	track length	=	10.67	ft
n=	number of tracks	=	2	
β=	slope angle	=	9.5	°
d=	depth of soil cover	=	1.5	ft
γ_{soil}=	unit weight of cover soil	=	120	lb/ft^3
δ_1=	interface friction angle, GC/soil	=	30	°
δ_3=	interface friction angle, GM/subgrade	=	29	°

Then;

P_c=	$W/(nT_wT_l)$	=	4.86	psi
N=	$P_c\cos\beta$	=	4.79	psi
T=	$P_c\sin\beta$	=	0.80	psi
N_g=	$N+\gamma_{soil}d\cos\beta$	=	5.97	psi
T_g=	$T+\gamma_{soil}d\sin\beta$	=	1.00	psi
F_1=	$N_g\tan\delta_1$	=	3.45	psi
F_2=	T_g	=	1.00	psi
F_3=	$N_g\tan\delta_3$	=	3.31	psi
FS=	F_1/T_g	=	3.45	
	F_3/T_g	=	3.31	

Since $F_1>T_g$ only a force equal to will be transferred to geomembrane liner. Therefore F_2 is equal to T_g (F_2= T_g= 3.31 psi). This force is then transferred to the geomembrane/subgrade interface, F_3, which produces a factor of safety = 3.31 for the system.

5.0 ATTACHMENTS

Caterpillar D6 Track-Type Tractor Specifications

6.0 CONCLUSION

The minimum factor of safety for the closure cap geosynthetics during construction is 3.31. Therefore, the 40 mil HDPE textured is sufficient for design of the closure cap system.

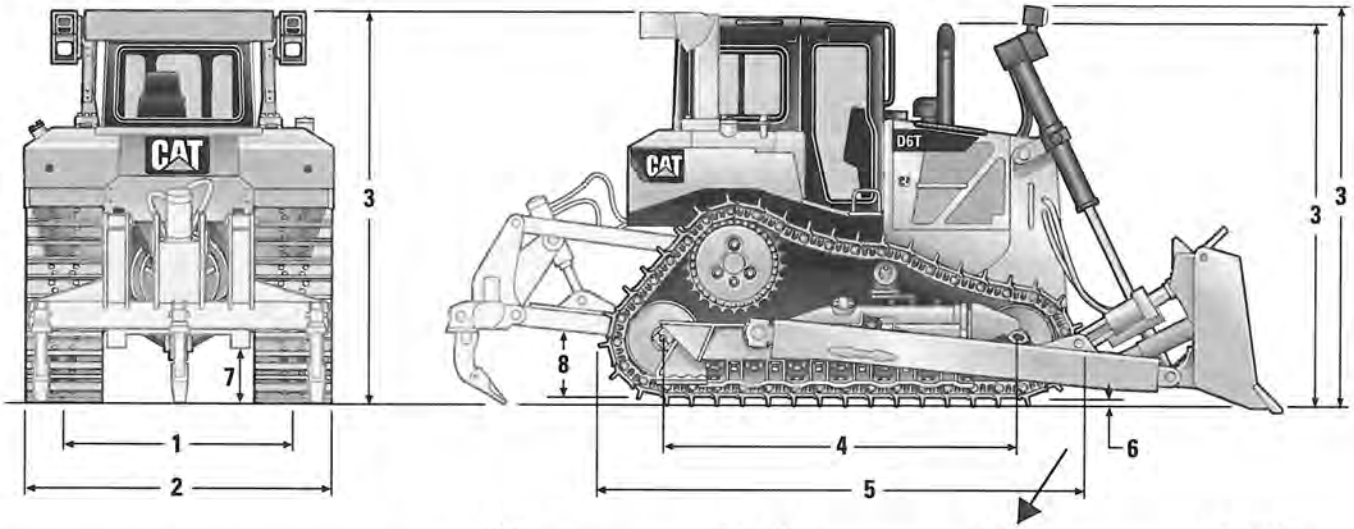
7.0 REFERENCES

Koerner, Robert M. *Designing with Geosynthetics, Fifth Edition*. Upper Saddle River, New Jersey: Pearson Prentice Hall, 2005. Print.

D6T Specifications

Dimensions

All dimensions are approximate.



	XW		XW VPAT		LGP		LGP VPAT	
1 Track gauge	2032 mm	6 ft 8 in	2286 mm	7 ft 6 in	2286 mm	7 ft 6 in	2286 mm	7 ft 6 in
2 Width of tractor								
Over trunnions	2950 mm	9 ft 8 in	—		3480 mm	11 ft 5 in	—	
Without trunnions (std. track)	2794 mm	9 ft 2 in	2997 mm	9 ft 10 in	3193 mm	10 ft 6 in	3150 mm	10 ft 4 in
3 Machine height from tip of grouser:								
Stack	3126 mm	10 ft 3 in	3126 mm	10 ft 3 in	3176 mm	10 ft 5 in	3176 mm	10 ft 5 in
ROPS	3169 mm	10 ft 5 in	3169 mm	10 ft 5 in	3219 mm	10 ft 7 in	3219 mm	10 ft 7 in
Premium Light Package	3310 mm	10 ft 10 in	3310 mm	10 ft 10 in	3360 mm	11 ft 0 in	3360 mm	11 ft 0 in
4 Length of track on ground	2840 mm	9 ft 4 in	2840 mm	9 ft 4 in	3250 mm	10 ft 8 in	3250 mm	10 ft 8 in
5 Length of basic tractor	3860 mm	12 ft 8 in	3860 mm	12 ft 8 in	4247 mm	13 ft 11 in	4247 mm	13 ft 11 in
With following attachments add:								
Drawbar	182 mm	7 in	182 mm	7 in	—		—	
Ripper Multi-Shank (tip at ground line)	1370 mm	4 ft 6 in	1370 mm	4 ft 6 in	1370 mm	4 ft 6 in	1370 mm	4 ft 6 in
Winch	517 mm	20 in	517 mm	20 in	397 mm	16 in	397 mm	16 in
S Blade	—		—		1168 mm	3 ft 10 in	—	
SU Blade	1271 mm	4 ft 2 in	—		—		—	
A Blade	1405 mm	4 ft 7 in	—		1475 mm	4 ft 10 in	—	
VPAT Blade	—		1504 mm	4 ft 11 in	—		1412 mm	4 ft 8 in
6 Height of grouser	65 mm	2.6 in	65 mm	2.6 in	65 mm	2.6 in	65 mm	2.6 in
7 Ground clearance	384 mm	15 in	384 mm	15 in	434 mm	17 in	434 mm	17 in
Track pitch	203 mm	8 in	203 mm	8 in	203 mm	8 in	203 mm	8 in
Number of shoes per side	41		41		45		45	
Number of rollers per side	7		7		8		8	
Standard shoe	760 mm	30 in	710 mm	28 in	915 mm	36 in	785 mm	31 in
Ground contact area (std. track)	4.31 m^2	6,681 in^2	4.03 m^2	6,247 in^2	5.95 m^2	9,223 in^2	5.10 m^2	7,905 in^2
Ground pressure*	43.9 kPa	6.36 psi	52.0 kPa	7.54 psi	33.5 kPa	4.86 psi	42.8 kPa	6.20 psi
8 Drawbar height	576 mm	23 in	576 mm	23 in	626 mm	25 in	626 mm	25 in
From ground face of shoe	511 mm	20 in	511 mm	20 in	561 mm	22 in	561 mm	22 in

* XL and XW with SU blade, LGP with S blade with no rear attachments unless otherwise specified and calculated per ISO 16754.

Golder Associates Richmond, Virginia	Subject: Veneer Slope Stability Analysis of Final Grade at the CEC Ash Landfill, Chesapeake, Virginia		
	Job No: 130-0193	Made by: DPM	Date: 9/3/2013
		Checked: KAL	
	Ref: SWP # 440	Reviewed: JRD	Sheet 1 of 1

Objective Determine veneer slope stability by means of a factor of safety of the static condition for the **geocomposite & cover soil interface.** Note that the site is not located in a seismic impact area as defined by the EPA (MHA > 0.1g)

Method

where $a = (W_a - N_a \cos\beta)(\cos\beta)$

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$

and where

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$$

and where Average of soil unit weight = 115 pcf @ 90% compaction and optimum moisture (w)

Calculations

β =	slope angle	=	9.5	degrees	6 :1
ϕ =	internal friction angle cover soil	=	30	degrees	(estimated from Das)
δ =	interface friction angle	=	30.0	degrees	(estimated from DS database)
c_a =	adhesion along interface	=	0	psf	(geocomposite vs. cover soil)
c =	cohesion of cover soil	=	0	psf	
L =	slope length	=	270	ft	
h =	cap thickness	=	2	ft	
γ =	unit weight of cover soil	=	115	pcf	

Then

$W_a = \gamma h^2(L/h - 1/\sin\beta - (\tan\beta)/2)$ = 59263.5292

$N_a = W_a\cos\beta$ = 58457.2244

$C_a = c_a(l - h/\sin\beta)$ = 0.00

$W_p = \gamma h^2/\sin 2\beta$ = 1418.37

$C = ch/\sin\beta$ = 0.00

Static Conditions

$a = (W_a - N_a \cos\beta)(\cos\beta)$ = 1579.85

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$ = -5759.36149

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$ = 526.59

$$\boxed{FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a} = 3.55}$$

References

1 Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003

2 Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".

3 Golder Direct Shear Database

Golder Associates Richmond, Virginia	Subject: Veneer Slope Stability Analysis of Final Grade of the CEC Ash Landfill, Chesapeake, Virginia		
	Job No: 130-0193	Made by: DPM	Date: 9/3/2013
		Checked: KAL	
	Ref: SWP #440	Reviewed: JBD	Sheet 1 of 1

Objective

Determine veneer slope stability by means of a factor of safety of the static condition for the **geocomposite & geomembrane interface.** Note that the site is not located in a seismic impact area as defined by the EPA (MHA > 0.1g)

Method

where

$a = (W_a - N_a \cos\beta)(\cos\beta)$

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$

and where

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$$

Calculations

β =	slope angle	=	9.5	degrees	6 :1
ϕ =	internal friction angle cover soil	=	30	degrees	(estimated from Das)
δ =	interface friction angle	=	25.0	degrees	(estimated from DS database)
c_a =	adhesion along interface	=	100	psf	(textured GM vs. GC)
c =	cohesion of cover soil	=	0	psf	
L =	slope length between benches	=	270	ft	
h =	cap thickness	=	2	ft	
γ =	unit weight of cover soil	=	115	pcf	

Then

$W_a = \gamma h^2(L/h - 1/\sin\beta - (\tan\beta)/2)$ = 59263.5292

$N_a = W_a\cos\beta$ = 58457.22437

$C_a = c_a(l - h/\sin\beta)$ = 25783.42

$W_p = \gamma h^2/\sin 2\beta$ = 1418.37

$C = ch/\sin\beta$ = 0.00

Static Conditions

$a = (W_a - N_a \cos\beta)(\cos\beta)$ = 1579.85

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$ = -8887.78741

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$ = 827.60

$$\boxed{FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a} = 5.53}$$

References

1 Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
2 Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".
3 Golder Direct Shear Database

CALCULATIONS

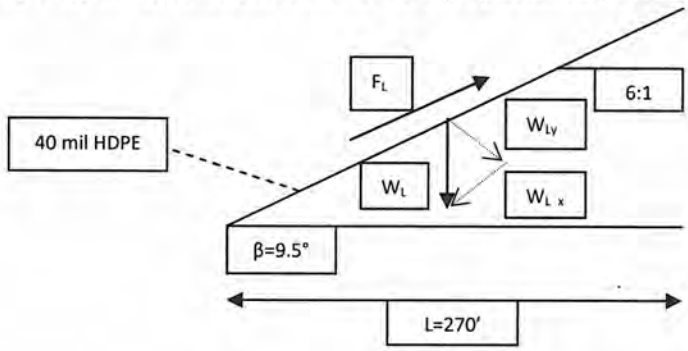
Date:	September 3, 2013	**Made by:**	DPM
Project No.:	130-0193	**Checked by:**	KAL
Subject:	Liner Self Weight Final Grades	**Reviewed by:**	JKD
Project:	CEC Ash Landfill – SWP #440		

1.0 OBJECTIVE

To calculate the factor of safety of the ability of the 40 mil HDPE textured geomembrane to support its own weight at the design slopes during construction.

2.0 METHOD

Use free-body diagram to calculate factor of safety by balancing forces.



Equations

$W_L = \gamma_L t_L L cos\beta$ — Where W_L= Weight of the Liner; γ_L= Unit Weight of Liner; t_L= Thickness of Liner; L= Length of Slope Base

$W_{Lx} = W_L sin\beta$ — Where W_{Lx}= Weight of Liner along Plane X

$W_{Ly} = W_L cos\beta$ — Where W_{Ly}= Weight of Liner along Plane Y

$F_L = W_{Ly} tan\delta$ — Where F_L= Force along Liner; δ= Geomembrane to Subgrade Interface Friction Angle; β= Angle of Slope

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3.0 ASSUMPTIONS

1. A 40 mil HDPE textured is used as the geomembrane.
2. The interface friction angle of the geomembrane to intermediate cover is 29.0 degrees.

4.0 CALCULATIONS

Where;

γ_L=	unit weight of liner	=	0.94	g/cm^3
		=	58.68	lb/ft^3
t_L=	thickness of liner	=	40	mil
		=	0.04	"
δ=	interface friction angle	=	29	°
β=	side slope angle	=	9.5	°
L=	length of slope base	=	270	ft

Then;

W_L=	$\gamma_L t_L(L/\cos\beta)$	=	53.55	lb/ft
W_{Lx}=	$W_L\sin\beta$	=	8.84	lb/ft
W_{Ly}=	$W_L\cos\beta$	=	52.81	lb/ft
F_L=	$W_{Ly}\tan\delta$	=	29.28	lb/ft
T=	$W_{Lx}-F_L$	=	-20.44	lb/ft
FS=	F_L/W_{Lx}	=	3.31	

Since the frictional resistance force along the line (F_L) is greater than the weight of the liner in the x-plane (W_{Lx}) then no tension is present in the liner. This creates a factor of safety greater than one which demonstrates that no tension is present in the liner due to self weight.

5.0 ATTACHMENTS

Geomembrane properties for 40 mil HDPE textured

6.0 CONCLUSIONS

The minimum factor of safety for the ability of geomembrane liner to support its own weight is 3.31. Therefore, the 40 mil HDPE textured is sufficient for design of the closure cap system.

7.0 REFERENCES

1) Koerner, Robert M. *Designing with Geosynthetics, Fifth Edition*. Upper Saddle River, New Jersey: Pearson Prentice Hall, 2005. Print.

High Density Polyethylene Micro Spike® Liner

Product Data

Property	Test Method	Values				
Thickness, nominal (mm)		30 (.75)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (min. ave.), mil (mm)	ASTM D5994*	29 (.71)	38 (.95)	57 (1.43)	76 (1.90)	95 (2.38)
Thickness (lowest indiv. for 8 of 10 spec.), mil (mm)	ASTM D5994*	27 (.68)	36 (.90)	54 (1.35)	72 (1.80)	90 (2.25)
Thickness (lowest indiv. for 1 of 10 spec.), mil (mm)	ASTM D5994*	26 (.64)	34 (.85)	51 (1.28)	68 (1.70)	85 (2.13)
***The thickness values may be changed due to project specifications (i.e., absolute minimum thickness)**						
Asperity Height (min. ave.), mil (mm)	GRI GM12/ASTM D7466	16 (.41)	16 (.41)	16 (.41)	16 (.41)	16 (.41)
Density, g/cc, minimum	ASTM D792, Method B	0.94	0.94	0.94	0.94	0.94
Tensile Properties (ave. both directions)	ASTM D6693, Type IV					
Strength @ Yield (min. ave.), lb/in width (N/mm)	2 in/minute	66 (11.6)	88 (15.4)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield (min. ave.), % (GL=1.3in)	5 specimens in each direction	13	13	13	13	13
Strength @ Break (min. ave.), lb/in width (N/mm)		66 (11.6)	88 (15.4)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Break (min. ave.), % (GL=2.0in)		350	350	350	350	350
Tear Resistance (min. ave.), lbs. (N)	ASTM D1004	23 (102)	30 (133)	45 (200)	60 (267)	72 (320)
Puncture Resistance (min. ave.), lbs. (N)	ASTM D4833	60 (267)	90 (400)	120 (534)	150 (667)	180 (801)
Carbon Black Content (range in %)	ASTM D4218	2 - 3	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views: 9 views in Cat. 1 or 2, and 1 view in Cat. 3				
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	300	300	300	300	300
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥100	≥100	≥100	≥100	≥100
Melt Flow Index, g/10 minutes	ASTM D1238, 190°C, 2.16kg	≤1.0	≤1.0	≤1.0	≤1.0	≤1.0
Oven Aging	ASTM D5721	80	80	80	80	80
with HP OIT, (% retained after 90 days)	ASTM D5885, 150°C, 500psi O_2					
UV Resistance	GRI GM11	20hr. Cycle @ 75°C/4 hr. dark condensation @ 60°C				
with HP OIT, (% retained after 1600 hours)	ASTM D5885, 150°C, 500psi O_2	50	50	50	50	50

These product specifications meet or exceed GRI's GM13

Supply Information (Standard Roll Dimensions)

Thickness		Width		Length		Area (approx.)		Weight (average)*	
mil	mm	ft	m	ft	m	ft^2	m^2	lbs	kg
30	.75	23	7	930	283.117	21,390	1,984	3,900	1,770
40	1.0	23	7	710	216.41	16,330	1,514.87	3,900	1,770
60	1.5	23	7	505	153.53	11,615	1,078	3,900	1,770
80	2.0	23	7	385	117.35	8,855	821	3,900	1,770
100	2.5	23	7	310	94.49	7,130	661	3,900	1,770

Notes:

All rolls are supplied with two slings. All rolls are wound on a 6 inch core. Special lengths are available on request. All roll lengths and widths have a tolerance of ±1%
**The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll lengths) or shipping requirements (i.e. international containerized shipments).*

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500 Garrison Road, Georgetown, South Carolina 29440 843-546-0600 800-373-2478 Fax: 843-527-2738
email: salesmkg@agruamerica.com www.agruamerica.com

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Golder Associates Richmond, Virginia	Subject: Veneer Slope Stability Analysis of Final Grade for the CEC Ash Landfill, Chesapeake, Virginia. SWP #440		
	Job No: 130-0193	Made by: DPM	Date: 9/3/2013
		Checked: JRD	
	Ref:	Reviewed: KAL	Sheet 1 of 1

Objective Determine the **minimum interface friction angle** value that will result in a factor of safety of 1.50 for geocomposite & cover soil interface under static conditions.

Method

where

$a = (W_a - N_a \cos\beta)(\cos\beta)$

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$

and where

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$$

and where Average of cover soil unit weight = 115 pcf @ 10% moisture (w)

Calculations

β =	slope angle	=	9.5	degrees	6 :1
ϕ =	internal friction angle cover soil	=	30	degrees	(estimated from Das)
δ =	interface friction angle	=	**13.2**	degrees	**Iterated to find FS = 1.50**
c_a =	adhesion along interface	=	0	psf	(geocomposite vs. cover soil)
c =	cohesion of cover soil	=	0	psf	
L =	slope length between benches	=	270	ft	
h =	cap thickness	=	2	ft	
γ =	unit weight of cover soil	=	115	pcf	

Then

$W_a = \gamma h^2(L/h - 1/\sin\beta - (\tan\beta)/2)$ = 59263.5292

$N_a = W_a\cos\beta$ = 58457.2244

$C_a = c_a(l - h/\sin\beta)$ = 0.00

$W_p = \gamma h^2/\sin 2\beta$ = 1418.37

$C = ch/\sin\beta$ = 0.00

Static Conditions

$a = (W_a - N_a \cos\beta)(\cos\beta)$ = 1579.85

$b = -\{(W_a - N_a\cos\beta)\sin\beta\tan\phi + (N_a\tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p\tan\phi)\}$ = -2509.93079

$c = (N_a\tan\delta + C_a)\sin^2\beta\tan\phi$ = 213.93

$$\boxed{FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a} = 1.50}$$

References

1 Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003

2 Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".

CALCULATIONS

Date:	September 3, 2013	**Made by:**	DPM
Project No.:	130-0193	**Checked by:**	JBD
Subject:	Closure Cap Geocomposite Material Calculations	**Reviewed by:**	KAL
Project:	**CEC ASH LANDFILL – SWP #440**		

This analysis is to determine the appropriate minimum material properties for the geocomposite of the closure cap liner system. Properties evaluated will be required geotextile permittivity, Apparent Opening Size (AOS) and minimum transmissivity of the geocomposite.

1.0 ASSUMPTIONS

- The protective cover soil material will come from off-site sources, typically SC or SM materials as found in tidewater, Virginia.

2.0 CALCULATIONS

2.1 Permittivity

The minimum permittivity (Ψ) of the geotextile component is calculated based on the maximum anticipated flow rate from the HELP model (closure cap model) and the hydraulic head associated with that flow (stated as inches of head on the geomembrane). The HELP model calculated maximum flow rate was 3,825 ft^3/day/ac at a hydraulic head of 0.132 inches.

$$Q = \frac{3{,}825\,\frac{ft^3}{day}}{ac} \times \frac{1\,ac}{43{,}560 ft^2} = \frac{0.0878\,\frac{ft^3}{day}}{ft^2}$$

Using Darcy's Law:

$$Q = kiA$$

also

$$i = \frac{\Delta h}{t}$$

and

$$\psi = \frac{k}{t}$$

$$Q = k\frac{\Delta h}{t}A = \frac{k}{t}\Delta hA$$

$$\frac{k}{t} = \frac{Q}{\Delta hA} = \psi$$

Where:

Q = flow rate (ft^3/day)
A = area (ft^2)
Δh = change in hydraulic head (ft)
Ψ = permittivity (day^{-1})
k = hydraulic conductivity (ft/day)
i = hydraulic gradient (ft/ft)
t = geocomposite thickness (ft)

$$\Psi = \frac{0.0878\,ft^3/day}{.0013\ ft \times 1\,ft^2} \times \frac{1\,day}{86{,}400\,seconds} = 7.82 \times 10^{-4}\,sec^{-1}$$

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Two analyses were made, one for the top 'crown' of the landfill with 4% minimum slopes, and another for the 6:1 sideslopes. Using manufacturer-published data for a 250-mil geocomposite, the resulting factors of safety for the 4% top and 6:1 sideslope are 4.7 and 10, respectively.

3.0 CONCLUSIONS

Based on the calculations presented herein, the selection of a double-sided geocomposite for the cap drainage layer is adequate, subject to the following material specifications:

- The nonwoven geotextile shall have an AOS not larger than 45 US Sieve. Typical material specifications are AOS = 80.
- The geonet core shall be at least 250 mil and have a transmissivity of 5.0×10^{-4} m^2 / sec.

4.0 REFERENCES

1. Koerner, Robert M., Designing with Geosynthetics, Fifth Edition, 2005

2. Qian, Xuede, Koerner, Robert M., and Gray, Donald H, Geotechnical Aspects of Landfill Design and Construction, 2002.

3. Ten Cate Nicolon Corporation, Geotextile Filter Design, Application, and Product Selection Guide, 2002.

Project:	CEC Ash Landfill - SWP #440		
P.N.:	130-0193	**Page:**	1 of 1
By:	DPM	**Date:**	9/3/13
Checked:	KAL	**Date:**	6/12/14
Reviewed:	JRD	**Date:**	
Subject:	Required Geocomposite Transmissivity 6:1 side slope		

Cap Drainage Layer - Geocomposite Drainage Net

General Data

Elevation Difference Between Drains =	45	ft			
Slope, X to 1 =	6	to 1			
Slope Angle, B =	9.46	degrees	=	16.7%	
Slope Length Between Drains, L =	270	ft	=	82.3	m
Qin Flow Gradient, i-in =	0.164				
Permeability of Cover Soils, Kveg =	1.00E-05	cm/sec		USCS 'SC' assumed	
Qin = (Kveg)(L) =	8.23E-06	m^2/sec			
Qout Flow Gradient, i-out = sinB =	0.164				

Qin = Qout

Qout = (θr)(i-out)

θr = (Qin)/(i-out)

Required Transmissivity, θr
(Qin)/(i-out) = 5.01E-05 m^2/sec

Ultimate Transmissivity, θu = 5.00E-04 m^2/sec — GSE 250 mil GC

Reduction Factors

Intrusion; Rfin =	1.3	>>>>	*Range: 1.3 to 1.5*
Creep; RFcr =	1.2	>>>>	*Range: 1.1 to 1.4*
Chemical Clogging; RFcc =	1.1	>>>>	*Range: 1.0 to 1.2*
Biological Clogging; RFbc =	1.3	>>>>	*Range: 1.2 to 1.5*

Product of Reduction Factors, PRF = 2.2308

Allowable Transmissivity, θa
(θu/PRF) = 2.24E-04 m^2/sec

Drainage Factor of Safety, DFS
(θa/θr) = 4.48

Minimum Drainage Factor of Safety, MDFS
MDFS = 2.0

Total Factor of Safety, TFS
(DFS x PRF) = 10.0

[ ] = *input data*

References:

1 *"Design Manual of Lateral Drainage Layers for Landfills"; Gregory N. Richardson, Ph.D., P.E. Jean-Pierre Giroud, E.C.P., Ph.D., Aigen Zhao, Ph.D., P.E.; 2000.*

2 *Manufacturer's data, various.*

Project:	CEC Ash Landfill - SWP #440		
P.N.:	130-0193	**Page:**	1 of 1
By:	DPM	**Date:**	9/3/13
Checked:	KAL	**Date:**	6/12/14
Reviewed:	JRD	**Date:**	
Subject:	Required Geocomposite Transmissivity 4% top cap slope		

Cap Drainage Layer - Geocomposite Drainage Net

General Data

Elevation Difference Between Drains =	5.5	ft		
Slope, X to 1 =	25.1	to 1		
Slope Angle, B =	2.28	degrees	=	4.0%
Slope Length Between Drains, L =	138	ft	=	42.1 m
Qin Flow Gradient, i-in =	0.040			
Permeability of Cover Soils, Kveg =	1.00E-05	cm/sec		USCS 'SC' assumed
Qin = (Kveg)(L) =	4.21E-06	m^2/sec		
Qout Flow Gradient, i-out = sinB =	0.040			

Qin = Qout

Qout = (θr)(i-out)

θr = (Qin)/(i-out)

Required Transmissivity, θr
(Qin)/(i-out) = 1.06E-04 m^2/sec

Ultimate Transmissivity, θu = 5.00E-04 m^2/sec — GSE 250 mil GC

Reduction Factors

Intrusion; Rfin =	1.3	>>>>	*Range: 1.3 to 1.5*
Creep; RFcr =	1.2	>>>>	*Range: 1.1 to 1.4*
Chemical Clogging; RFcc =	1.1	>>>>	*Range: 1.0 to 1.2*
Biological Clogging; RFbc =	1.3	>>>>	*Range: 1.2 to 1.5*

Product of Reduction Factors, PRF = 2.2308

Allowable Transmissivity, θa
(θu/PRF) = 2.24E-04 m^2/sec

Drainage Factor of Safety, DFS
(θa/θr) = 2.12

Minimum Drainage Factor of Safety, MDFS
MDFS = 2.0

Total Factor of Safety, TFS
(DFS x PRF) = 4.7

[ ] = *input data*

References:

1 *"Design Manual of Lateral Drainage Layers for Landfills"; Gregory N. Richardson, Ph.D., P.E. Jean-Pierre Giroud, E.C.P., Ph.D., Aigen Zhao, Ph.D., P.E.; 2000.*

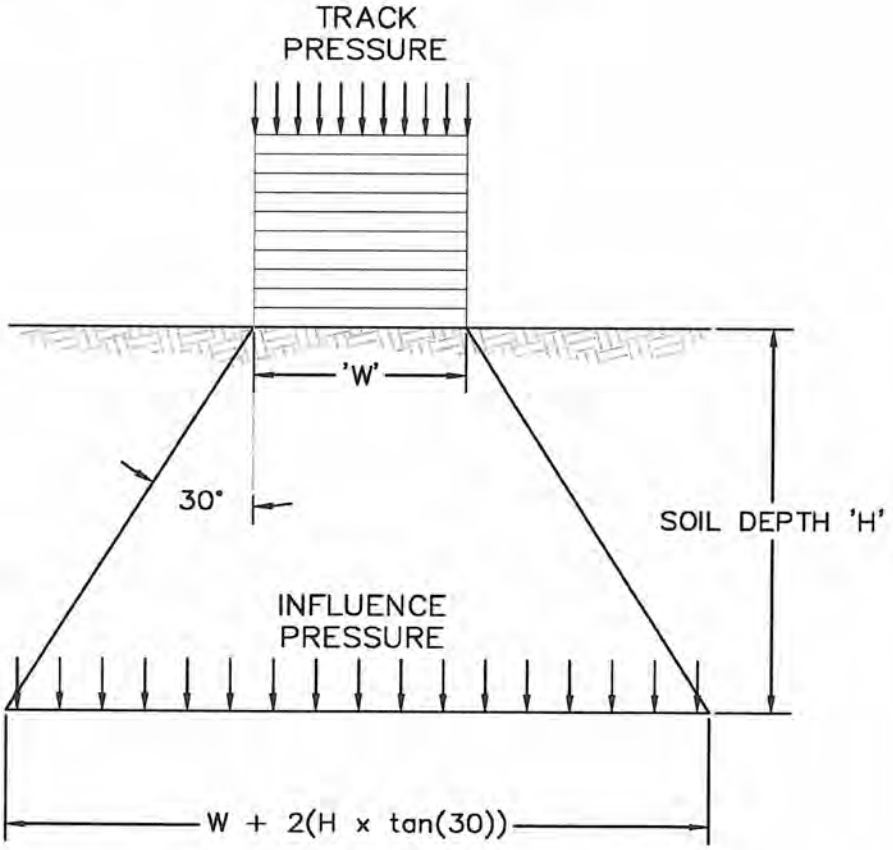
2 *Manufacturer's data, various.*

Project:	CEC Ash Landfill - SWP #440		
P.N.:	130-0193	**Page:**	1 of 1
By:	DPM	**Date:**	10/14/13
Checked:	JRD	**Date:**	6/6/14
Reviewed:	KAL	**Date:**	6/12/14
Subject:	Ash Pond Bearing Capacity		

Ground Influence Pressure of CAT 320 Hydraulic Excavator

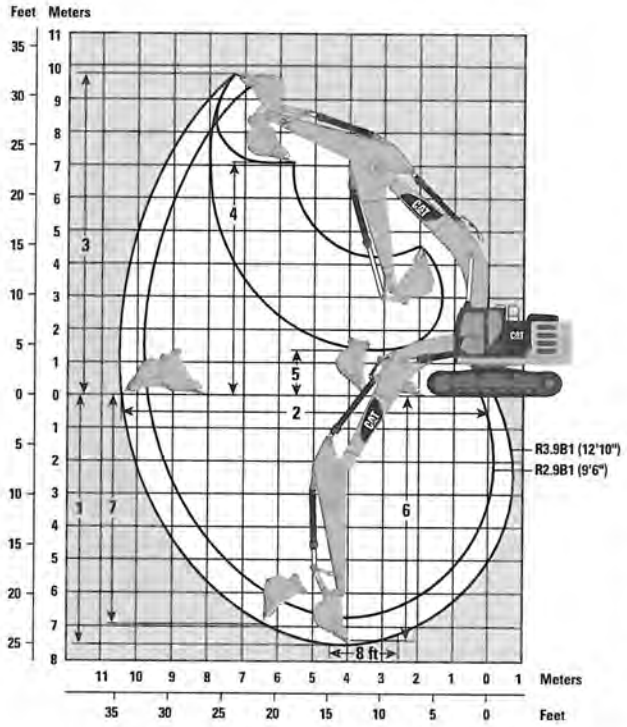
Track Pressure	6.6	PSI
Track Width	2.0	feet
Soil Unit Weight	120.0	lb/ft^3

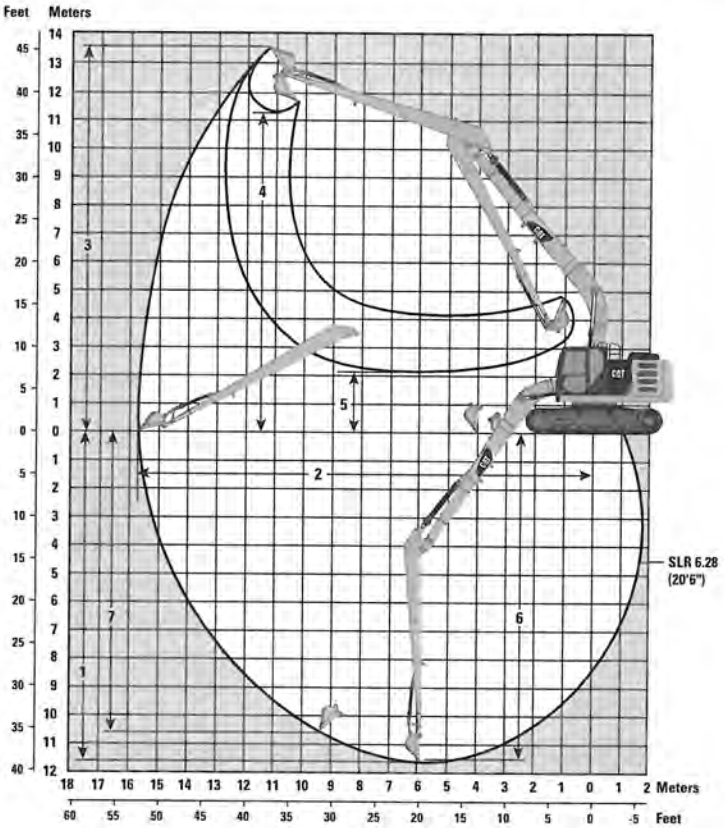
	* Per unit length (1') of machine track			
Soil Depth, ft	Soil Pressure, PSF	Track Influence Area, ft^2	Track Pressure, PSF	Total Pressure, PSF
0	0.0	2.00	950.0	950.0
1	120.0	3.15	602.3	722.3
2	240.0	4.31	440.9	680.9
3	360.0	5.46	347.7	707.7
4	480.0	6.62	287.0	767.0
5	600.0	7.77	244.4	844.4
6	720.0	8.93	212.8	932.8



Working Ranges

All dimensions are approximate.





Stick	Heavy Duty and Extreme Service Booms 5.7 m (18'8") 3.9B1 (12'10")*	2.9B1 (9'6")**	Super Long Reach Boom 8.85 m (29'0") Super Long Reach 6.28 m (20'6")***
	mm (ft)	mm (ft)	mm (ft)
1 Maximum Digging Depth	7580 (24'10")	6720 (22'1")	11 690 (38'4")
2 Maximum Reach at Ground Level	10 680 (35'0")	9860 (30'9")	15 720 (51'6")
3 Maximum Cutting Height	9890 (32'4")	9370 (30'7")	13 590 (44'6")
4 Maximum Loading Height	7030 (23'0")	6490 (21'4")	11 290 (37'0")
5 Minimum Loading Height	1310 (4'4")	2170 (7'1")	2090 (6'9")
6 Maximum Depth Cut for 2440 mm (8'0") Level Bottom	7440 (24'4")	6550 (21'6")	11 590 (38'0")
7 Maximum Vertical Wall Digging Depth	6910 (22'7")	5060 (16'7")	10 670 (35'0")

*Cat 900 mm (36"), 0.81 m³ (1.06 yd³) GD bucket with 1557 mm (5'1") tip radius.

**Cat 1200 mm (48"), 1.19 m³ (1.56 yd³) HD bucket with 1571 mm (5'2") tip radius.

***Cat 1100 mm (44"), 0.61 m³ (0.8 yd³) ditch cleaning bucket with 1092 mm (3'7") tip radius.

Operating Weight and Ground Pressure

	320E L			
	790 mm (31") Triple Grouser Shoes		600 mm (24") Triple Grouser Shoes	
	kg (lb)	kPa (psi)	kg (lb)	kPa (psi)
Boom HD – 5.7 m (18'8")				
3.9B1 (12'10") HD	22 200 (48,940)	35.0 (5.08)	21 500 (47,400)	44.7 (6.48)
2.9B1 (9'6") HD	22 200 (48,940)	35.1 (5.10)	21 600 (47,620)	44.9 (6.51)
2.9B1 (9'6") ES	22 400 (49,380)	35.4 (5.13)	21 700 (47,840)	45.2 (6.56)
2.9B1 (9'6") ES with Heavy Counterweight	24 700 (54,450)	38.9 (5.64)		
Boom ES – 5.7 m (18'8")				
3.9B1 (12'10") HD	22 500 (49,600)	35.5 (5.15)	21 800 (48,060)	45.4 (6.58)
2.9B1 (9'6") HD	22 600 (49,820)	35.7 (5.18)	21 900 (48,280)	45.6 (6.61)
2.9B1 (9'6") ES	22 700 (50,040)	35.9 (5.21)	22 100 (48,720)	45.9 (6.66)
Super Long Reach Boom – 8.85 m (29'0")				
6.28 m (20'6") SLR	23 500 (51,810)	37.1 (5.38)	22 800 (50,270)	47.4 (6.87)

Bucket and Stick Forces

	Heavy Duty and Extreme Service Booms 5.7 m (18'8")		Super Long Reach Boom 8.85 m (29'0")
Stick	**3.9B1 (12'10")**	**2.9B1 (9'6")**	**Super Long Reach 6.28 m (20'6")**
B1 – Family Bucket	**kN (lbf)**	**kN (lbf)**	**kN (lbf)**
General Duty			
Bucket Digging Force (SAE)	125.9 (28,300)	125.9 (28,300)	51.2 (11,500)
Stick Digging Force (SAE)	87.8 (19,700)	103.9 (23,400)	35.8 (8,000)
Heavy Duty			
Bucket Digging Force (SAE)	124.4 (28,000)	133.5 (30,000)	
Stick Digging Force (SAE)	87.6 (19,700)	103.2 (23,200)	
Severe Duty			
Bucket Digging Force (SAE)	124.4 (28,000)	133.5 (30,000)	
Stick Digging Force (SAE)	87.6 (19,700)	103.2 (23,200)	