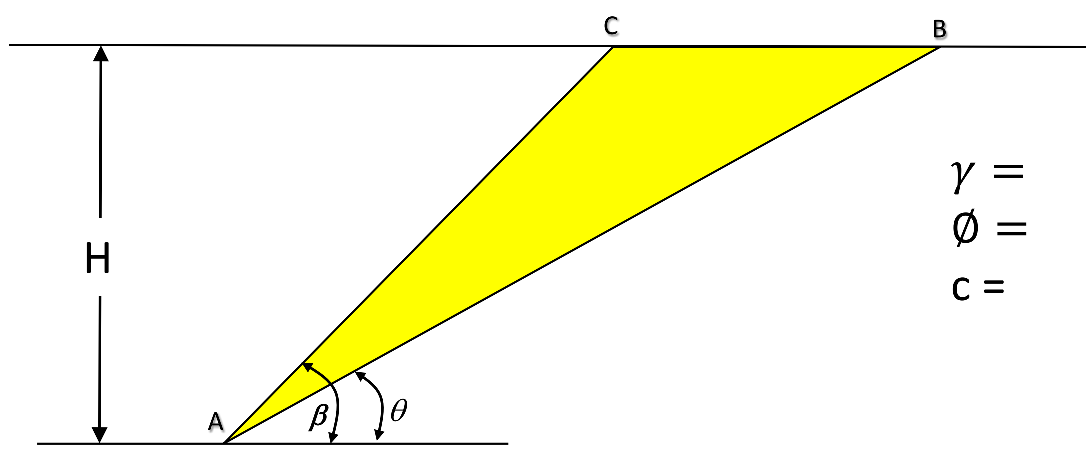
Slope Stability Analysis
Homework #5
Spring 2022

Problem 1

The following figure shows a 15-ft cut through two soil strata. The lower is a highly impermeable cohesive soil. Shearing strength data between the two strata are as follows:

Cohesion=400 psf
Angle of internal friction= 25°
Unit weight of the upper layer= 105 pcf
Height of the slope, H= 10 ft
$\beta = 45^{o}$
$\theta = 30^{o}$

Find if the slope is safe or not



Problem 2

A 45° slope is excavated to a depth of 8 m in a deep layer of saturated clay of unit weight 19 kN/m^3: the relevant shear strength parameters are $c_u = 65$ kN/m^2 and $\phi_u = 0$. Determine the factor of safety for the trial failure surface specified in Fig. 9.3.

To scale

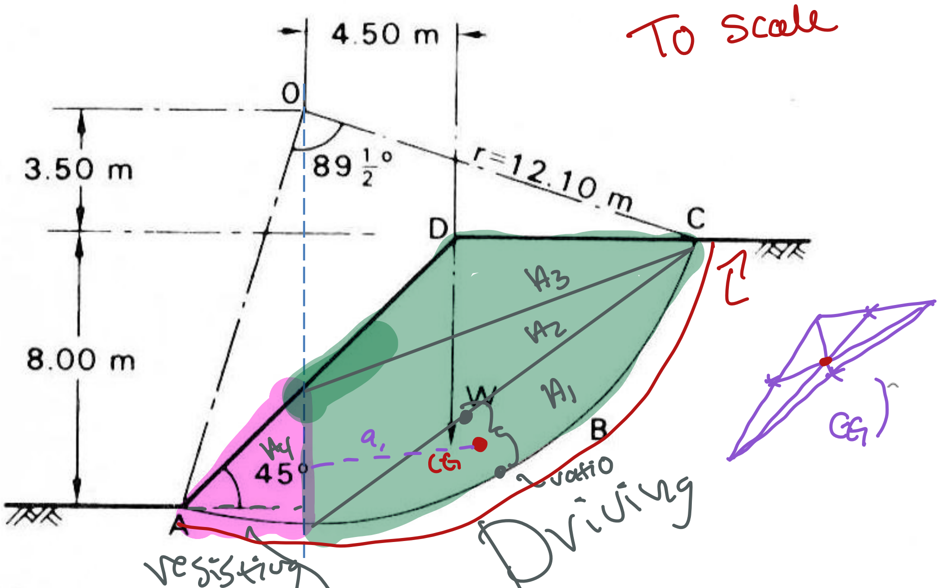
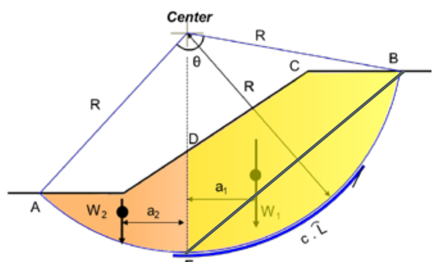


Figure 9.3 Example 9.1.

approximate triangle



Resisting Moment (M_R) = $W_2 \times a_2$ + C x R

Driving Moment (M_D) = $W_1 \times a_1$

$$\frac{A_4 \gamma a_4 + C \times \tau \times r}{A_1 \gamma a_2 + A_2 \gamma a_2 + \ldots}$$

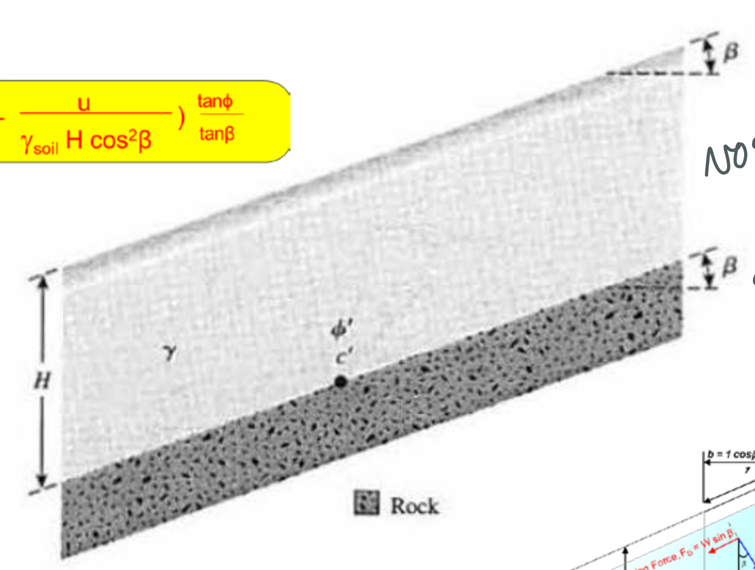
give CG and A

Find a

Problem 3 Sometimes exam

Refer to Figure 4, Given: $\beta = 20^o$, $\gamma = 18\ kN/m^3$, $\phi = 25^o$, and $c' = 14\ kN/m^2$. Find the height, H, that will have a factor of safety, F_s of 2.5 against sliding along the soil-rock interface.

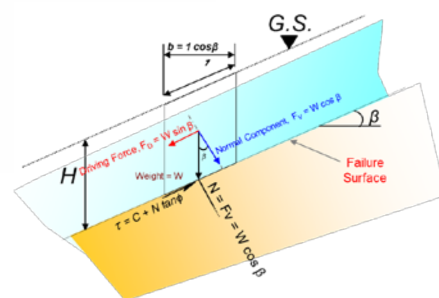
$$FS = \frac{c}{\gamma_{soil}\, H \cos\beta \sin\beta} + \left(1 - \frac{u}{\gamma_{soil}\, H \cos^2\beta}\right) \frac{\tan\phi}{\tan\beta}$$



No seepage

seepage

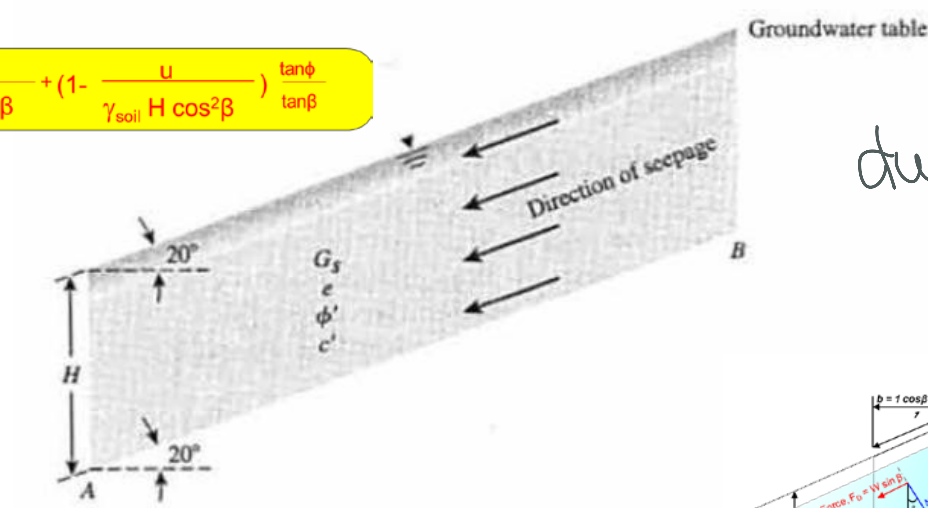
Figure 4



Problem 4

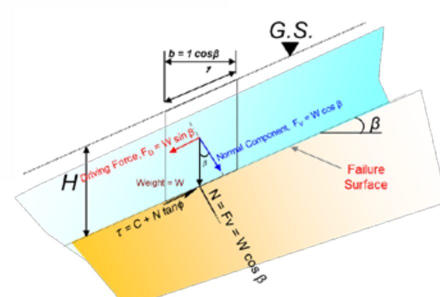
For the infinite slope shown in Figure 5, find the factor of safely against sliding along the plane *AB,* given that H = 20 ft. $\gamma = 110$ pcf, $\phi = 20^o$, and $c' = 500$ psf. Note that there is seepage through the soil and that the groundwater table coincides with the ground surface.

$$FS = \frac{c}{\gamma_{soil}\, H \cos\beta \sin\beta} + \left(1 - \frac{u}{\gamma_{soil}\, H \cos^2\beta}\right) \frac{\tan\phi}{\tan\beta}$$



dw = H

Figure 5



determine scale

Problem 5 Exam!

Find the factor of safety for a 20 meter high 2H - I V slope shown in the following figure using ordinary method of slices. Each slice has a width of 5 meters.

γ = 16 kN/m^3

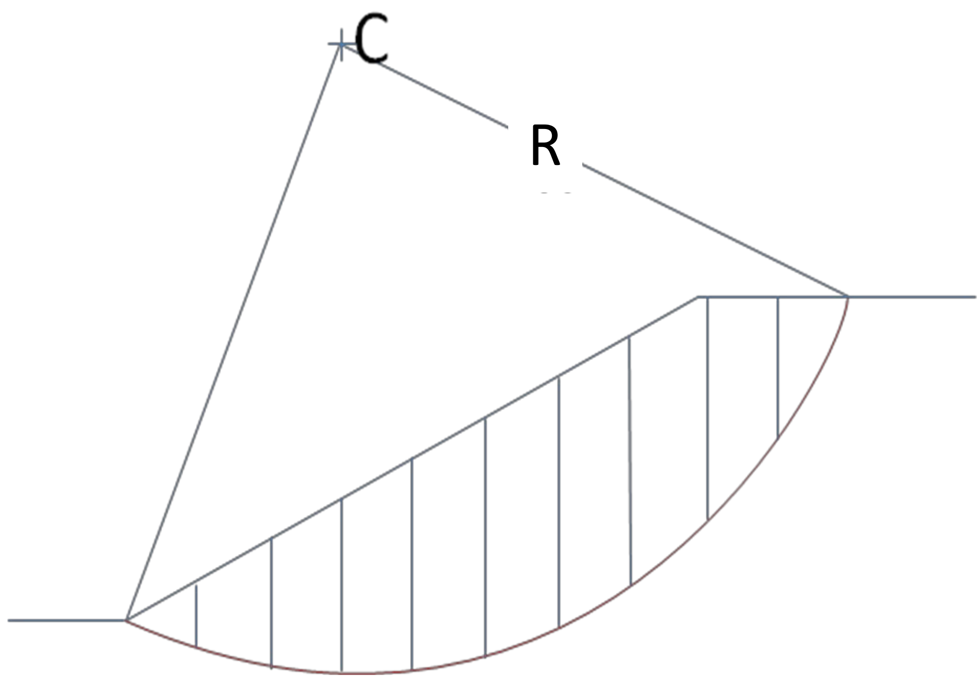
c =20 *kPa*

ϕ = *20O*

R =38.1 *m*

give H θ_n

U



Slice	Width Δx (ft)	Ave Height (ft)	Weight (Kips)	θ_i	$W_i \sin \theta_i$	$W_i \cos \theta_i$	u_i	Δl_i	$U_i = u_i \Delta l_i$	$N_i = W_i \cos\theta_i - U_i$
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

$$\text{F.S.} = \frac{cL + \tan\varphi \sum_{i=1}^{i=n}(W_i cos\theta_i - u_i \Delta l_i)}{\sum_{i=1}^{i=n} W_i sin\theta_i}$$

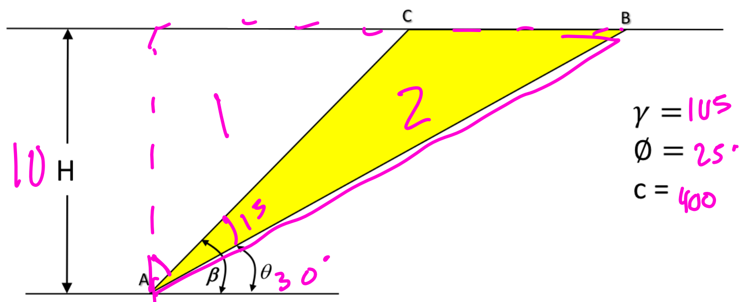
Problem 1

The following figure shows a 15-ft cut through two soil strata. The lower is a highly impermeable cohesive soil. Shearing strength data between the two strata are as follows:

Cohesion=400 psf
Angle of internal friction= 25°
Unit weight of the upper layer= 105 pcf
Height of the slope, H= 10 ft
$\beta = 45^\circ$
$\theta = 30^\circ$

Find if the slope is safe or not

Trial & Error method



Resisting force = $cL + N\tan\phi$

$90 - \beta = 45$

Assume F.S. = 2

$$\phi_d = \tan^{-1}\left(\frac{\tan\phi}{(F.S.)}\right)$$

$$\phi_d = \tan^{-1}\left(\frac{\tan(25)}{2}\right) \rightarrow = 13.12^\circ$$

$$C_d = \frac{\gamma H}{2}\left[\frac{\sin(\beta-\theta)(\sin\theta - \cos\theta\tan\phi_d)}{\sin\beta}\right]$$

$$= \frac{105(10)}{2}\left[\frac{\sin(45-30)[\sin(30) - \cos(30)\times\tan(\ )]}{\sin 45}\right]$$

(525; .2588; .5; .707)

$C_d = 57.28$

$$C_d = \frac{c}{F.S._c} = \frac{400}{57.28} = 6.98$$

Not equal

trial 2

Assume F.S. = 4

$$\phi d = \tan^{-1}\left(\frac{\tan \phi}{F.S.}\right) = \tan^{-1}\left(\frac{\tan(25)}{4}\right) = 6.649°$$

$$Cd = \frac{105(10)}{2}\left[\frac{\sin(45-30)[\sin(30) - \cos(30) \times \tan(6.649)]}{\sin 45}\right]$$

$Cd = 76.68$

$$\frac{400}{76.68} = F.S.C = 5.216$$ closer

trial 3

Assume F.S. = 5

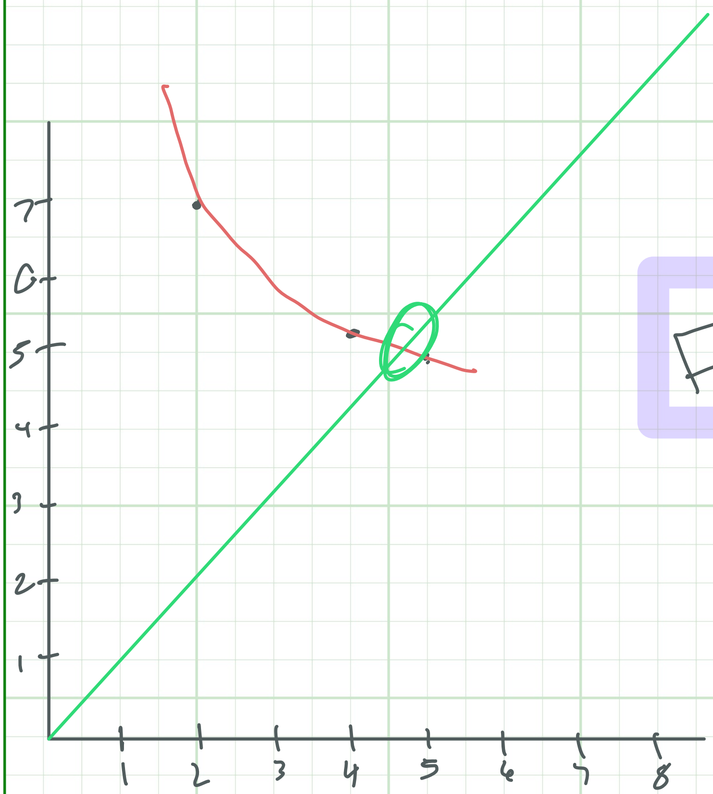
$$\tan^{-1}\left(\frac{\tan(25)}{5}\right) = 5.328°$$

$$Cd = \frac{105(10)}{2}\left[\frac{\sin(45-30)[\sin(30) - \cos(30) \times \tan(5.328)]}{\sin 45}\right]$$

$Cd = 80.56$

$$\frac{400}{80.56} = 4.96$$

Assumed F.S.	Calculated
2	6.98
4	5.261
5	4.96



F.S. = 5

Other method for #1

$\frac{1}{2} b H = \text{area}$

$\frac{1}{2}(\ )10$

$\tan(45) = \frac{b}{10} \quad = 10$

$\frac{1}{2} 10^2 = 50$ triangle 1

$= \frac{1}{2}(17.328)(10)$

$\tan(90-30) = \frac{b}{10}$

$= 86.60$ triangle 2

$b = 17.328$

$86.60 - 50 = 36.60 \text{ ft}^2$ area

$W = \text{area} \times \gamma \quad = 36.60 \times 105$

$W = 3843.3$ lb/ft

Resisting Force

$cL + N \tan\phi$

$\hookrightarrow w \cos\beta$

$400(20) + 3843.3\cos(30)\tan(25)$

$= 9552.04$

Driving Force

$W \sin\beta$

$= 3843.3 \sin(30)$

$= 1921.6$

$L_{AB} = \cos(90-30) = \frac{10}{L} \quad = 20 \text{ ft}$

$FS = \frac{9552.04}{1921.6} = 4.97$ Safe!

2.

A 45° slope is excavated to a depth of 8 m in a deep layer of saturated clay of unit weight 19 kN/m^3: the relevant shear strength parameters are $c_u = 65$ kN/m^2 and $\phi_u = 0$. Determine the factor of safety for the trial failure surface specified in Fig. 9.3.

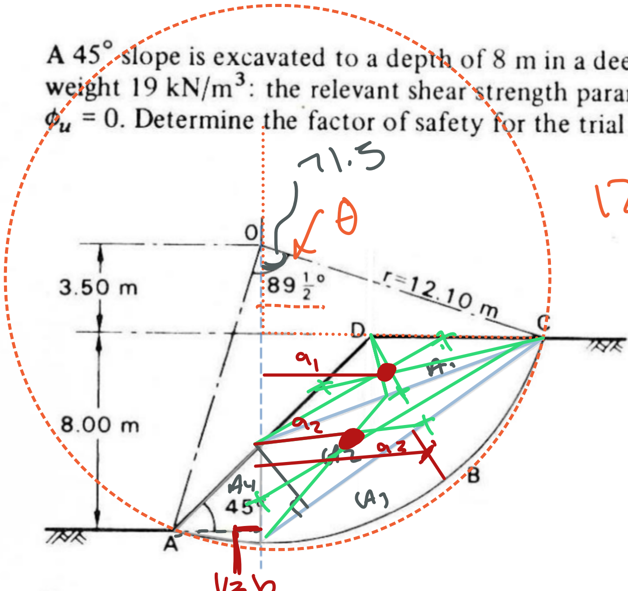
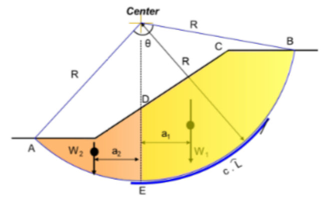


Figure 9.3 Example 9.1.

12.10m = 1.1 meter



Resisting Moment (M_R) = $W_2 \times a_2 + C \times R$

Driving Moment (M_D) = $W_1 \times a_1$

$\gamma = 19$ kN/m^3

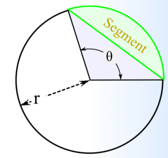
$C_u = 65$ kN/m^2

$\phi_u = 0$

Area of Segment

The Area of a Segment is the area of a sector minus the triangular piece (shown in light blue here).

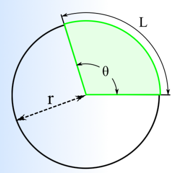
There is a lengthy reason, but the result is a slight modification of the Sector formula:



$A = ½ × (θ - \sin θ) × r^2$

Area of Segment = $\frac{\theta - \sin(\theta)}{2} \times r^2$ (when θ is in radians)

Area of Segment = $\left(\frac{\theta \times \pi}{360} - \frac{\sin(\theta)}{2}\right) \times r^2$ (when θ is in degrees)



$L = θ × r$

Arc Length

The arc length (of a **Sector or Segment**) is:

$L = \theta \times r$ (when θ is in radians)

$L = \theta \times \frac{\pi}{180} \times r$ (when θ is in degrees)

arc length = θ × r ← radians

$\left(12.10 \times 89.5 \frac{\pi}{180}\right) = 18.9m$

Area 1

.2

b1 .5 b2 .6

$\frac{12.10}{x} = \frac{1.1}{.2}$

h = 2.2

$b_1 = 5.5$

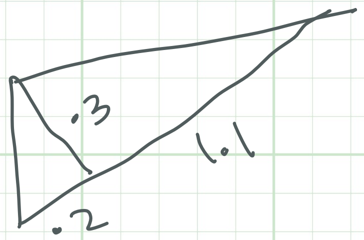
$b_2 = 6.60$

= .5(5.5)(2.2) + .5(6.6)(2.2)

Area 1 = 13.31 m^2

$a_1 = .55 \rightarrow 6.05$

Area 2



$\frac{1}{2}(2.2)(3.3) + \frac{1}{2}(3.3)(12.1)$

$A_2 = 23.6\ m^2$

$a_2 = .4 \rightarrow 4.4$

Area 3 $= 21.93$

$\left(\frac{71.3 \times \pi}{360} - \frac{\sin(71.5)}{2}\right) \times 12.1^2$

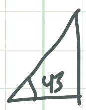
centroid $= \frac{4b}{3\pi}$ → height circle $= .25 \rightarrow 2.75$

$= 1.167\ m$

$= .106$ on ruler

$a_3 = .6 \longrightarrow 6.6\ m$

Area 4



$\frac{1}{2}(3.3)(3.85)$

$= 6.35$

$a_4 = 1/3\, b =$

$\frac{1}{3}(3.3) = 1.1$

$$\frac{A_4 \gamma a_4 + C \times l \times r}{A_1 \gamma a_1 + A_2 \gamma a_2 + \ldots}$$

$$\frac{6.35(19)1.1 + 65 \times 18.9 \times 12.1}{13.31(19)(6.05) + 23.6(19)(4.4) + 21.93(19)(6.6)}$$

F.S. = 2.4

3.

Refer to Figure 4, Given: β = 20°, γ = 18 kN/m³, ϕ = 25°, and c' = 14 kN/m². Find the height, H, that will have a factor of safety, F_s of 2.5 against sliding along the soil-rock interface.

$$FS = \frac{c}{\gamma_{soil} H \cos\beta \sin\beta} + \left(1 - \frac{u}{\gamma_{soil} H \cos^2\beta}\right) \frac{\tan\phi}{\tan\beta}$$

$\beta = 20$

$\gamma = 18$

$\phi = 25$

$c' = 14$

F.S. 2.5

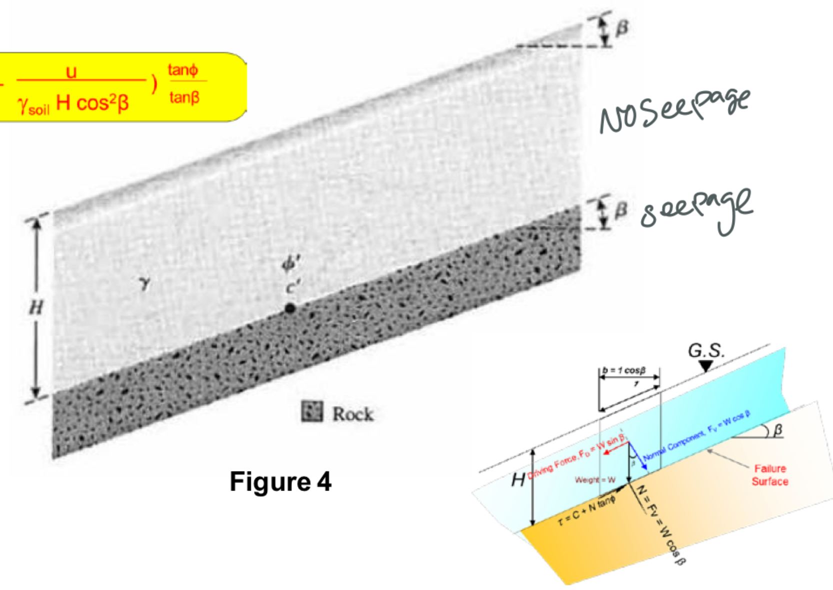


Figure 4

$$2.5 = \frac{14}{18\, H \cos(20)(\sin(20))} + \left(1 - \frac{0?}{18\, H \cos^2(20)}\right) \frac{\tan(25)}{\tan(20)}$$

$$2.5 = \frac{2.4200}{H} + 1.2811$$

$$1.2188 = \frac{2.4200}{H}$$

H = 1.9855 m

4.

For the infinite slope shown in Figure 5, find the factor of safely against sliding along the plane *AB*, given that H = 20 ft. γ = 110 pcf, ϕ = 20°, and c' = 500 psf. Note that there is seepage through the soil and that the groundwater table coincides with the ground surface.

$$FS = \frac{c}{\gamma_{soil} H \cos\beta \sin\beta} + \left(1 - \frac{u}{\gamma_{soil} H \cos^2\beta}\right) \frac{\tan\phi}{\tan\beta}$$

$H = 20$
$\gamma = 110$
$\phi = 20$
$c' = 500$
$\beta = 20°$

$d_w = H$

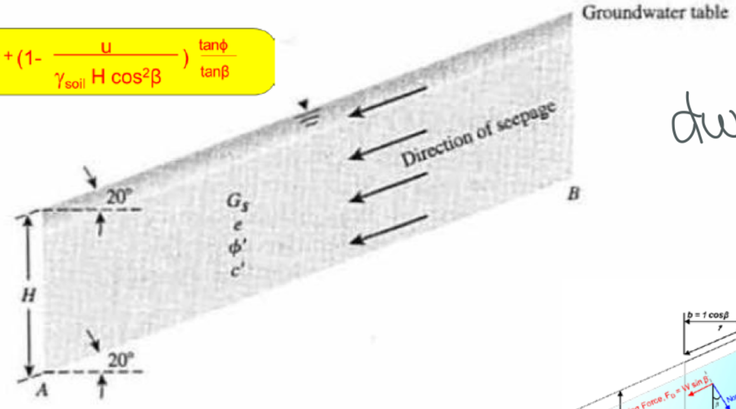
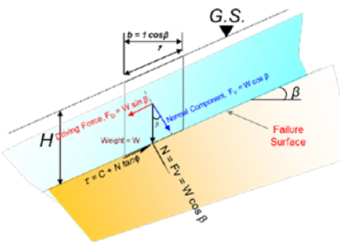


Figure 5



$U = \gamma_w \times Z$

$Z = d_w \cos\beta (\cos\beta)$ (20)

$Z = 20 \cos(20) \cos(20)$

$Z = 17.66$

$U = 17.66 \times 62.4 = 1102.011$

$$F.S. = \frac{500}{110 \times 20 \cos(20) \sin(20)} + \left(1 - \frac{1102.011}{110 \times 20 \times \cos^2(20)}\right) \frac{\tan(20)}{\tan(20)}$$

.70714 + .432727

F.S. = 1.14

5.

Find the factor of safety for a 20 meter high 2H - I V slope shown in the following figure using ordinary method of slices. Each slice has a width of 5 meters.

γ = 16 kN/m^3

c =20 kPa

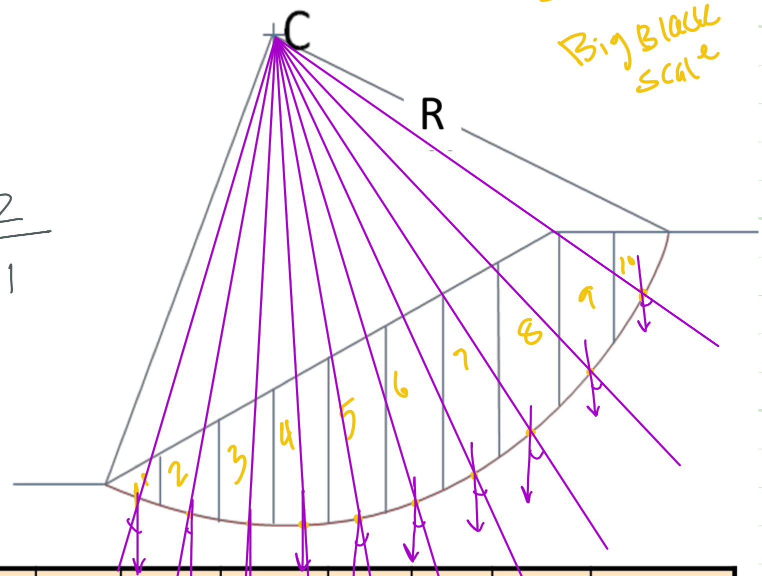
ϕ = 20O

R =38.1 m

5m = .2
Big Black scale

$$\frac{5m}{x\,m} = \frac{.2}{.1}$$

5m = .2



from ruler

Slice	Width Δx (~~ft~~) m	Ave Height (~~ft~~) m	Weight (~~Kips~~) kN/m	θ_i	$W_i \sin\theta_i$	$W_i \cos\theta_i$	u_i	Δl_i	$U_i = u_i \Delta l_i$	$N_i = W_i \cos\theta_i - U_i$
1	5	2.5	200	-11°	-38.16	196.32	0	5	0	196.32
2		7.5	400	-8°	-83.50	594.16	0	6.25	0	594.16
3	8	11.25	900	-4°	-62.78	897.81	0	5	0	897.81
4	7	15	1200	4°	83.71	1197.08	0	5	0	1197.08
5	6	16.25	1300	14°	314.5	1261.38	0	5	0	1261.38
6	c	17.5	1400	19°	455.79	1323.73	0	5	0	1323.73
7	4	18.75	1500	22	561.91	1390.78	0	6.25	0	1390.78
8	3	17.5	1400	34°	782.87	1160.65	0	7.5	0	1160.65
9	2	13.75	1100	36	646.56	889.92	0	10	0	889.92
10	1	6.25	500	51°	388.57	316.66	0	11.25	0	316.66
					3049.47	9226.49		66.25	0	9226.49

$$F.S. = \frac{cL + \tan\varphi \sum_{i=1}^{i=n}(W_i cos\theta_i - u_i \Delta l_i)}{\sum_{i=1}^{i=n} W_i sin\theta_i}$$

$$F.S. = \frac{20 \times 66.25 + \tan(20)(9226.47)}{3049.47}$$

F.S. = 1.535