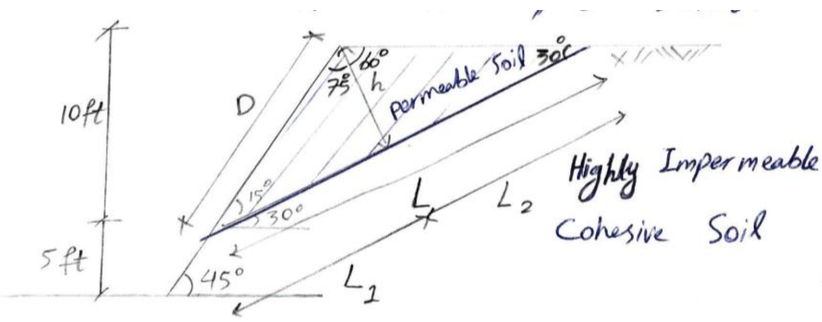
Home Work 6 Solution

Problem 1)



Shear strength between layers: 150 $\frac{lb}{ft^2}$

Angle of internal friction: 25°

$\gamma_{upper\ soil} = 105 \frac{lb}{ft^3}$

Find the factor of safety against the sliding:

$\beta = 45^\circ$

$\alpha = 30^\circ$

$\phi' = 25^\circ$

$c' = 150\ psf$

$\gamma = 105\ pcf$

$FS_\phi = tg\phi / tg\phi_d$

$FS_c = c / c_d$

$D \cos 45^\circ = 10 ft \Rightarrow D = 10' / \cos 45 = 14.14'$

$L_1 = D \cos 15^\circ = 14.14' \times \cos 15 = 13.66'$

$h = D \cos 75^\circ = 14.14' \times \cos 75 = 3.66'$

$h = tg\, 30^\circ \times L_2 \Rightarrow L_2 = \frac{3.66'}{tg 30} = 6.34'$

$L = L_1 + L_2 = 13.66' + 6.34' = 20'$

$W = \frac{1}{2} \times h \times L \times \gamma = \frac{1}{2} \times 3.66' \times 20' \times 105 = 3843\ lb$

$$FS = \frac{C_d L + W \cos\alpha\, tg\, \phi_d}{W \sin\alpha} \Rightarrow tg\, \phi_d = \frac{FS\,(W \sin\alpha) - \frac{C}{FS} L}{W \cos\alpha}$$

* Assume $FS_c = 1.5 \Rightarrow C_d = \frac{C}{FS_c} = \frac{C}{1.5} \Rightarrow tg\,\phi_d = \frac{(1.5)\,(3843 \sin 30) - \frac{150}{1.5}(20)}{3843 \times \cos 30}$

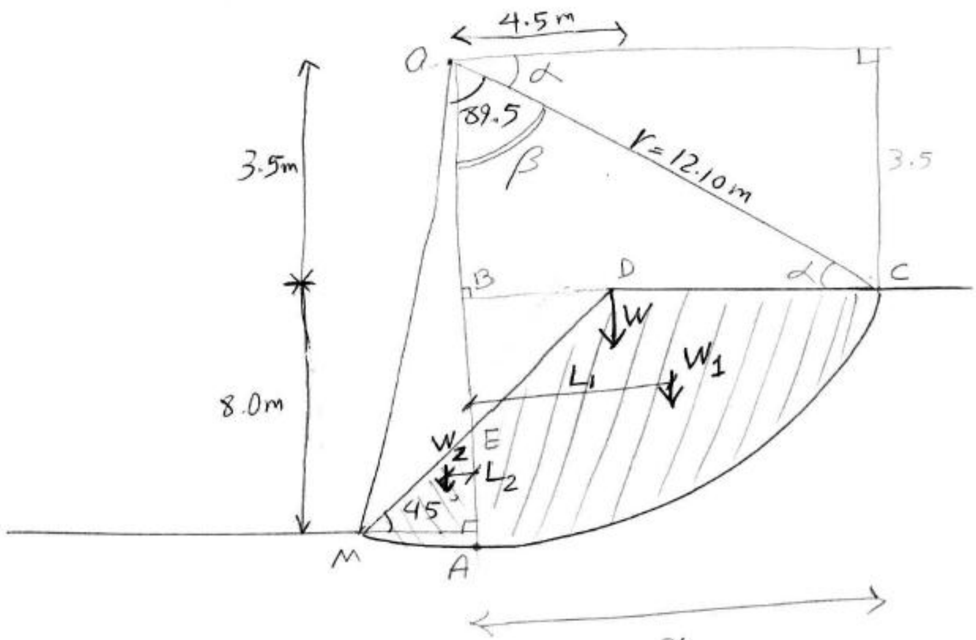
$\Rightarrow tg\,\phi_d = 0.2651 \Rightarrow FS_\phi = \frac{tg\,25}{0.2651} = 1.76$

* Assume $FS_c = 1.6 \Rightarrow C_d = \frac{150\ psf}{1.6} \Rightarrow tg\,\phi_d = 0.3615 \Rightarrow FS_\phi = \frac{tg\,25}{0.3615} = 1.29$

* Assume $FS_c = 1.54 \Rightarrow C_d = \frac{150}{1.54} \Rightarrow tg\,\phi_d = 0.3038 \Rightarrow FS_\phi = \frac{tg\,25}{0.3038} = 1.53$

$\Rightarrow \boxed{FS = 1.54}$

Problem 2)



Arc length $= L_a = r \times \frac{89.5^\circ \times \pi}{180} = 18.9m$

$\alpha = \sin^{-1} \frac{3.5}{12.10} = 16.8$

$x = 12.1 \cos\alpha = 11.583$

Area (AEDC) = Area (OAC) − Area (OBC) − Area (BED)

$\beta = 90^\circ - \alpha = 73.19^\circ$

Area (OAC) $= \pi \times 12.1^2 \times \frac{73.19^\circ}{360^\circ} = 93.51 \; m^2$

Area (AEDC) $= 93.15 - \frac{11.583 \times 3.5}{2} - \frac{4.5 \times 4.5}{2} = \underbrace{63.114 \; m^2}_{\text{Active Area}} = A$

Area (MEA) $\approx \frac{3.5^2}{2} = \underbrace{6.125 \; m^2}_{\text{Resisting Area}} = A_2$

$L_2 = \frac{3.5}{3} = 1.167$

$L_1 = \frac{W \times 4.5 - W_2 \times L_2}{W_1} = \frac{A \times \gamma \times 4.5 - A_2 \times \gamma \times L_2}{A_1 \; \gamma_1}$

$$\Rightarrow L_1 = \frac{(63.114 + 6.125) \times 4.5 - 6.125 \times 1.167}{63.125} = 4.836$$

$$FS = \frac{C_u L_a r + \gamma A_{resist} \times L_2}{\gamma A_{active} \times L_1} = \frac{65 \frac{kN}{m^2} \times 18.9 \times 12.1 + 19 \frac{kN}{m^3} \times 6.125 \times 1.1}{19 \times 63.114 \times 4.836}$$

$$\Rightarrow \boxed{FS = 2.587}$$

Problem 3)

Since the given angle of internal friction (ϕ) of 10° is greater than 3°, the failure surface will be a toe circle.

Try F.S.$_{\phi}$ = 1

$$\tan \phi_{required} = \frac{\tan \phi_{given}}{F.S._{\phi}} = \frac{\tan 10^\circ}{1}$$ (assumed)

$$\phi_{required} = 10^\circ$$

With $\phi_{required} = 10^\circ$ and $\beta = 45^\circ$, from Fig. 13-10,

$$N_s = 9.2 = 0.10869$$ based on $\frac{c}{\gamma H} = N_s$

$$N_s = \frac{\gamma H}{c} \qquad (13\text{-}12)$$

$$\gamma = 120 \text{ lb/ft}^3$$ given

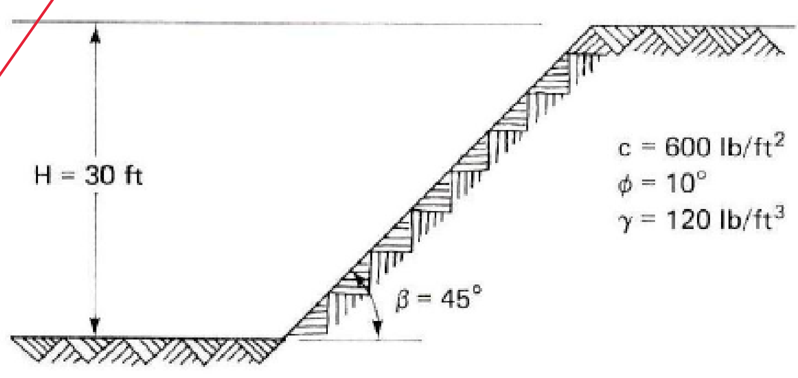
$$H = 30 \text{ ft}$$ given

$$9.2 = \frac{(120 \text{ lb/ft}^3)(30 \text{ ft})}{c_{required}}$$: $\frac{C_{req} \text{ or } C_d}{120 \times 30} = N_s = 0.$

$$c_{required} = 391 \text{ lb/ft}^2$$ ✓

$$F.S._{c} = \frac{c_{given}}{c_{required}} = \frac{600 \text{ lb/ft}^2}{391 \text{ lb/ft}^2} = 1.53$$

Since F.S.$_{\phi}$ and F.S.$_{c}$ are not the same value, another value of F.S.$_{\phi}$ will be tried.



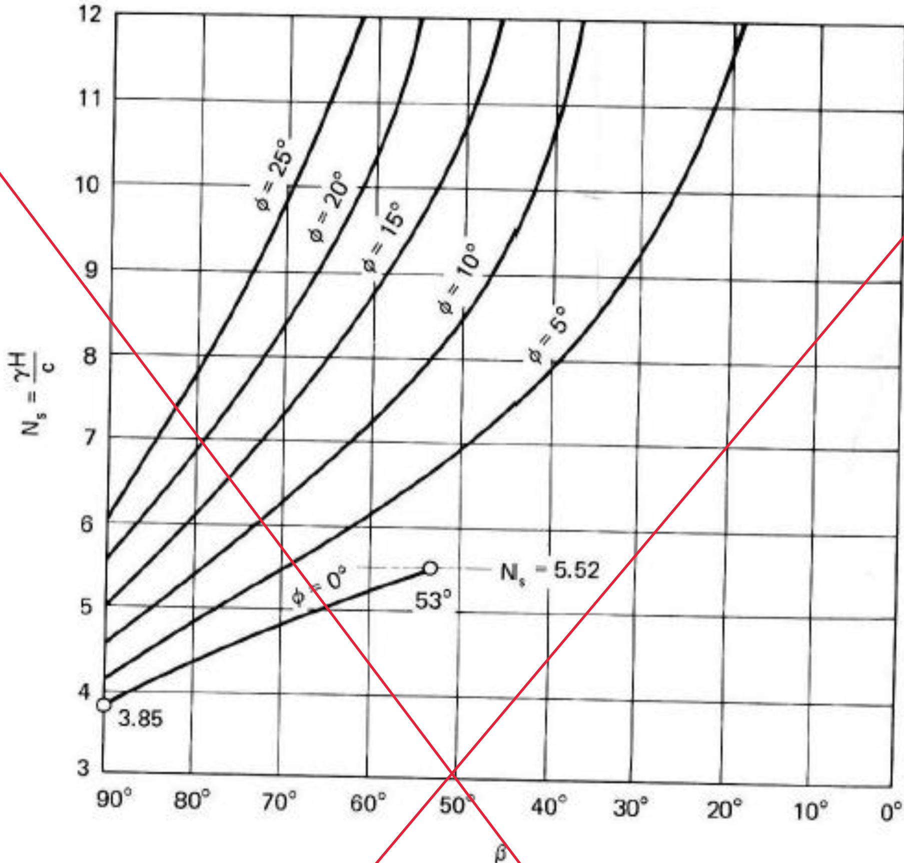


FIGURE 13-10 Stability numbers for soils having cohesion and friction. [5, 6]

Try F.S.$_\phi$ = 1.2

$$\tan \phi_{required} = \frac{\tan \phi_{given}}{F.S._\phi} = \frac{\tan 10°}{1.2} = 0.147$$

$$\phi_{required} = 8.36°$$

With $\phi_{required} = 8.36°$ and $\beta = 45°$, from Fig. 13-10,

$$N_s = 8.6$$

$$c_{required} = \frac{(120 \text{ lb/ft}^3)(30 \text{ ft})}{8.6} = 419 \text{ lb/ft}^2$$

$$F.S._c = \frac{c_{given}}{c_{required}} = \frac{600 \text{ lb/ft}^2}{419 \text{ lb/ft}^2} = 1.43$$

Again, F.S.$_\phi$ and F.S.$_c$ are not the same value; hence, another value of F.S.$_\phi$ will be tried.

Try F.S.$_{\phi}$ = 1.5

$$\tan \phi_{\text{required}} = \frac{\tan \phi_{\text{given}}}{\text{F.S.}_{\phi}} = \frac{\tan 10^\circ}{1.5} = 0.118$$

$$\phi_{\text{required}} = 6.73^\circ$$

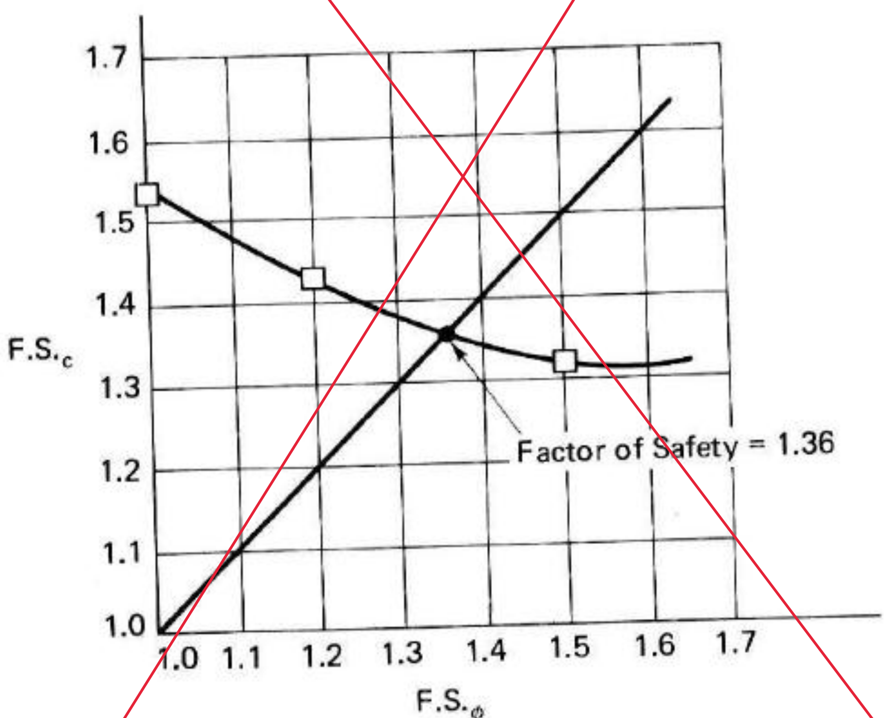
With $\phi_{\text{required}} = 6.73^\circ$ and $\beta = 45^\circ$, from Fig. 13-10,

$$N_s = 7.9$$

$$c_{\text{required}} = \frac{(120\ \text{lb/ft}^3)(30\ \text{ft})}{7.9} = 456\ \text{lb/ft}^2$$

$$\text{F.S.}_c = \frac{c_{\text{given}}}{c_{\text{required}}} = \frac{600\ \text{lb/ft}^2}{456\ \text{lb/ft}^2} = 1.32$$

Again, F.S.$_{\phi}$ and F.S.$_c$ are not the same value. Rather than continue a trial-and-error solution, plot the values computed. From Fig. 13-12, the factor of safety of the slope against failure is observed to be 1.36.



Problem 4)

$\beta = 20°, \quad \gamma = 18\frac{kN}{m^3}, \quad \emptyset' = 25°, \quad c' = 14\ kN/m^2, \quad FS = 2.5$

$$F_s = \frac{c'}{\gamma H \cos^2\beta \tan\beta} + \frac{\tan\phi'}{\tan\beta}$$

$$2.5 = \frac{14}{(18)(H)(\cos^2 20)(\tan 20)} + \frac{\tan 25}{\tan 20}$$

$$2.5 = \frac{2.42}{H} + 1.28$$

$$H = \mathbf{1.98\ m}$$

Problem 5)

$H = 20\ ft, \quad \emptyset' = 20°, \quad c' = 500\ Ib/ft^2$

We assume:

$G_S = 2.7$

$e = 0.6$

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e} = \frac{(2.7+0.6)62.4}{1+0.6} = 128.7\ \text{lb/ft}^3$$

$$\gamma' = 128.7 - 62.4 = 66.3\ \text{lb/ft}^3$$

$$F_s = \frac{c'}{\gamma_{sat} H \cos^2\beta \tan\beta} + \frac{\gamma'}{\gamma_{sat}}\frac{\tan\phi'}{\tan\beta}$$

$$= \frac{500}{(128.7)(20)(\cos^2 20)(\tan 20)} + \frac{66.3}{128.7}\frac{\tan 20}{\tan 20} = 0.604 + 0.515 \approx \mathbf{1.12}$$

Problem 6)

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

Name of the angles in table is different from the equation

Slice	Width (m)	Height (m)	Weight (kN)	c (kPa)	ϕ (deg)	α (deg)	β (deg)
1	5.0	2.0	160.0	20.0	20.0	−19.2	26.57
2	5.0	6.0	480.0	20.0	20.0	−11.4	26.57
3	5.0	9.0	720.0	20.0	20.0	−3.8	26.57
4	5.0	11.5	920.0	20.0	20.0	3.8	26.57
5	5.0	13.5	1,080.0	20.0	20.0	11.4	26.57
6	5.0	14.5	1,160.0	20.0	20.0	19.2	26.57
7	5.0	15.0	1,200.0	20.0	20.0	27.4	26.57
8	5.0	14.5	1,160.0	20.0	20.0	36.2	26.57
9	5.0	12.0	960.0	20.0	20.0	46.2	0.0
10	5.0	5.0	400.0	20.0	20.0	58.6	0.0

Slice	Base Length (m)	N' Eq. 6-29 (kN)	$(C' + N' \tan\phi)$ From Eq. 6-33 (kN)	$A - 1$ Eq. 6-34 (kN)
1	5.29	151.1	160.89	−52.6
2	5.10	470.5	273.27	−94.9
3	5.01	718.4	361.70	−47.7
4	5.01	918.0	434.34	61.0
5	5.10	1,058.7	487.35	213.5
6	5.29	1,095.5	504.61	381.5
7	5.63	1,065.4	500.40	552.2
8	6.20	936.1	464.62	685.1
9	7.22	664.5	386.32	692.9
10	9.60	208.4	267.79	341.4
			3,841.28	2,732.4

Ordinary Method of Slices, FOS = 1.406