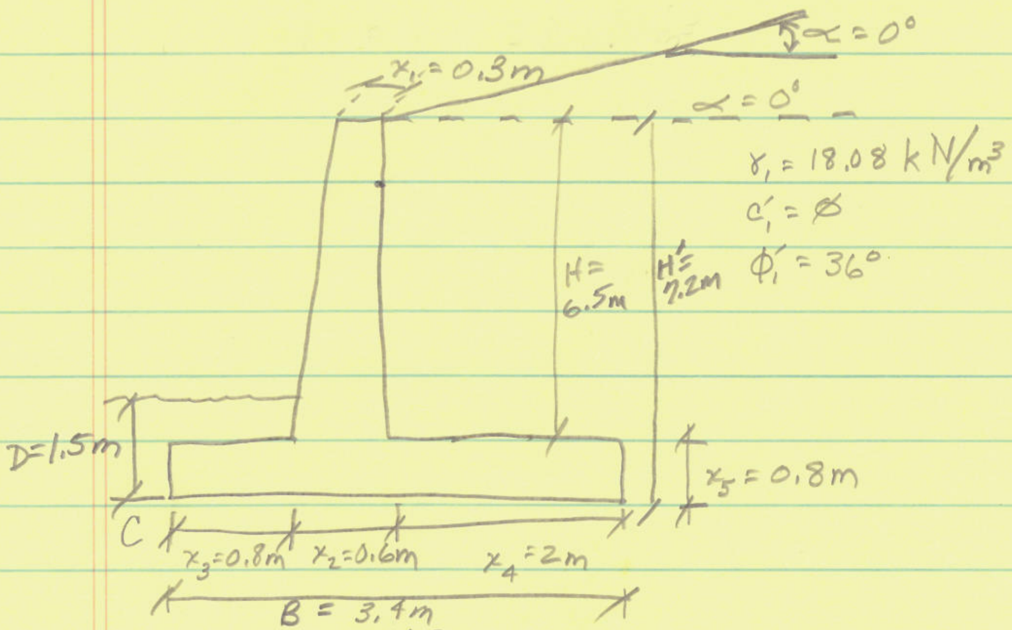
Chapter 8 Problems

David Dammon

8.2 Calculate the factor of safety with respect to overturning, sliding & bearing capacity.

$\gamma_{concrete} = 23.58\ kN/m^3$

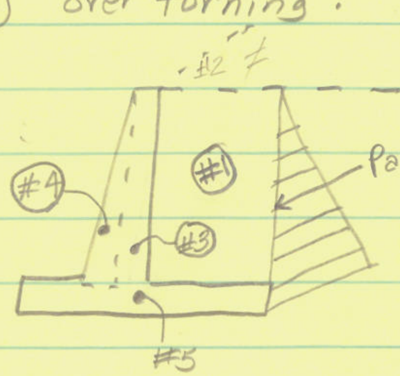


$\gamma_2 = 19.65\ kN/m^3$

$c'_2 = 30 kN/m^2$

$\phi'_2 = 15°$

(a) over turning: $FS_{overturning} = \dfrac{\Sigma M_R}{\Sigma M_o}$



	Area	Weight/length	Moment Arm (c)	Moment kN-m/m
1	13	235.04	2.4m	564.10
3	1.95	45.98	1.25m	57.48
4	0.975	22.99	0.8+0.2 1.0	22.99
5	2.72	64.14	1.7	109.04

$\Sigma V = 368.15\ kN/m$ $\Sigma M = 753.61$

Area 1 = 2m × 6.5 = 13 m^2

3 = .3 × 6.5 = 1.95 m^2

4 = $\frac{1}{2}[6.5 \times (.6 - .3)] = 0.975 m^2$

5 = .8 × 3.4 = 2.72 m^2

$W_1 = \gamma_1 \times A_1 = 18.08 \times 13 = 235.04$

$W_3 = \gamma_c \times A_3 = 23.58 \times 1.95 = 45.98$

$W_4 = 23.58 \times 0.975 = 22.99$

$W_5 = 23.58 \times 2.72 = 64.14$

#8.2 Continued

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[Tbl 7.1] $K_a = 0.2596$

[7.10] $P_a = \frac{1}{2}\gamma H'^2 K_a - 2\cancel{c'}^{\,\phi} H\sqrt{K_a}$

$P_a = \frac{1}{2}(18.08\ KN/m^3)(6.5m + 0.8m)^2(0.2596)$

$P_a = 125.06\ kN/m$

$P_v = \phi$ because $\alpha = \phi°$

$P_h = P_a = 99.15\ kN/m$

[8.3] $\Sigma M_o = P_h\left(\frac{H'}{3}\right) = (125.06)\left(\frac{6.5+0.8}{3}\right) = 304.31\ kN$

[8.2] $F_s = \frac{\Sigma M_R}{\Sigma M_o} = \frac{753.61\ kN}{304.31\ kN} = \boxed{2.48}$ overturning

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(b) Sliding

$\delta' = \frac{2}{3}\phi' = \frac{2}{3}(15°) = 10°$

$k_p = \tan^2(45 + \phi_2'/2)$

$C_a' = \frac{2}{3}c_2' = \frac{2}{3}(30) = 20\ kN/m^2$

$k_p = 1.698$

[7.63] $P_p = \frac{1}{2}k_p\gamma_2 D^2 + 2c_2'\sqrt{k_p}\,D = \frac{1}{2}(1.698)(19.65)(1.5)^2 + 2(30)\sqrt{1.698}(1.5)$

$P_p = 154.81$

$\cos\alpha = \cos 0° = 1$

[8.10] $FS_{SLIDING} = \frac{(\Sigma V)(\tan\delta') + Bc_a' + P_p}{P_a \cos\alpha}$

$= \frac{(368.15)(\tan 10°) + (3.4)(20) + 154.81}{125.06\ (1)}$

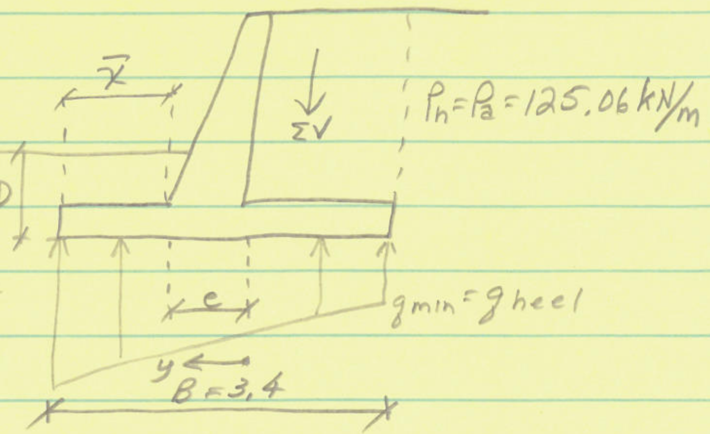
$\boxed{FS = 2.3}$

But sometimes $FS_{SLIDING}$ does not include P_p

$\boxed{FS_{SLIDING} = 1.06}$

#8.2 Continued

(c) Bearing Capacity



[8.17] $\overline{CE} = \dfrac{M_{net}}{\Sigma V} = \dfrac{\Sigma M_R - \Sigma M_o}{\Sigma V}$

$= \dfrac{753.61 - 304.31}{368.15}$

$\overline{CE} = 1.22$

[8.18] $e = \dfrac{B}{2} - \overline{CE} = \dfrac{3.4}{2} - 1.22 = 0.4796$

[8.20] $q_{max} = q_{toe} = \dfrac{\Sigma V}{B}\left(1 + \dfrac{6e}{B}\right) = \dfrac{368.15}{3.4}\left(1 + \dfrac{6(0.4796)}{3.4}\right)$

$q_{toe} = 199.92\ kN$

$\rightarrow B' = B - 2e = 3.4 - 2(0.4796) = 2.44\ m$

$\rightarrow q = \gamma_2 D = 19.65 \times 1.5 = 29.475\ kN/m^2$

$F_{qd} = 1 + 2\tan\phi'_2 (1 - \sin\phi'_2)^2 \dfrac{D}{B'} = 1 + 2\tan(15)(1 - \sin(15))^2\left(\dfrac{1.5}{2.44}\right)$

$\rightarrow F_{qd} = 1.181$

$F_{cd} = F_{qd} - \left(\dfrac{1 - F_{qd}}{N_c \tan\phi'_2}\right)$

(pg 144) Tbl 3.3 $\phi'_2 = 15°$

N_c	N_q	N_γ
10.98	3.94	2.65

$\rightarrow F_{cd} = 1.181 - \left(\dfrac{1 - 1.181}{10.98 \tan 15°}\right) = 1.243$

$\rightarrow F_{\gamma d} = 1$

$\psi° = \tan^{-1}\left(\dfrac{P_a \cos\alpha}{\Sigma V}\right) = \tan^{-1}\left(\dfrac{(125.06\ kN/m)(\cos 0°)}{368.15\ kN/m}\right)$

$\psi° = 18.76$

$\rightarrow F_{ci} = F_{qi} = \left(1 - \dfrac{\psi°}{90}\right)^2 = \left(1 - \dfrac{18.76}{90}\right)^2 = 0.6265$

$F_{\gamma i} = \left(1 - \dfrac{\psi°}{\phi'_2}\right)^2$

$\rightarrow F_{\gamma i} = \left(1 - \dfrac{18.76}{15}\right)^2 = 0.0628$

8.2 Contined

Bearing Capacity

[8.22] $q_u = c_2' N_c F_{cd} F_{ci} + q N_q F_{qd} F_{qi} + \frac{1}{2} \gamma_2 B' N_\gamma F_{\gamma d} F_{\gamma i}$

$= (30)(10.98)(1.243)(0.6265) + (29.475)(3.94)(1.181)(0.6265)$

$+ \frac{1}{2}(19.65)(2.44)(2.65)(1)(0.0628)$

$q_u = 256.52 + 85.93 + 3.99 = 346.44 \ kN/m^2$

[8.23] $FS_{(bearing)} = \dfrac{q_u}{q_{max}} = \dfrac{346.44}{199.92} = \boxed{1.73}$

David Dammon

#8.5 Refer to figure below for the design of a gravity retaining wall for earthquake conditions $k_v = \phi$ & $k_h = 0.3$

a) what should be the weight of the wall for a zero displacement condition with a Factor of Safety = 2?

b) What should be the weight of the wall for an allowable displacement of 50.8mm? $A_v = 0.15$, $A_a = 0.25$, $FS = 2$
0.0508m

a) [8.28] $CIE = \dfrac{\sin(\beta - \delta') - \cos(\beta - \delta')\tan\phi'_2}{(1-k_v)(\tan\phi'_2 - \tan\theta')}$

$\tan\theta' = \dfrac{k_h}{1-k_v} = \dfrac{0.3}{1-0} = 0.3$

$$CIE = \frac{\sin(90° - 15°) - \cos(90° - 15°)\tan 36°}{(1-0)(\tan 36° - 0.3)}$$

$CIE = 1.82$

K_{ae} (Tbl 7.6) $= 0.563$

[8.27] $W_w = \left[\frac{1}{2}\gamma_1 H^2 (1-k_v) K_{ae}\right] CIE$

$= \left[\frac{1}{2}(18 kN/m^3)(7m)^2(1-0)(0.563)\right] \times 1.82 = 451.9 kN/m$

#8.5 continued

a) with a FS=2 $451.9 \times 2 = \boxed{903.8\,kN/m}$

b) $k_k = A_a \left(\dfrac{0.2\,A_v^2}{A_a\,\Delta}\right)^{0.25} = 0.25\left(\dfrac{(0.2)(0.15)^2}{(0.25)\left(\frac{50.8}{25.4}\right)}\right)^{0.25}$

convert to inches

$k_k = 0.077$

$\tan\theta' = \dfrac{k_h}{1-k_v} = \dfrac{0.077}{1-0} = 0.077$

$CIE = \dfrac{\sin(90-15) - \cos(90-15)\tan 36^\circ}{(1-0)(\tan 36 - 0.077)} = 1.198$

K_{ae} (Tbl 7.6) $= 0.368$

$W_w = \left[\frac{1}{2}(18\,kN/m^3)(7m)^2(1-0)(0.368)\right] \times 1.198 = 194.4\,kN/m$

with FS=2 $194.4 \times 2 = \boxed{388.8\,kN/m}$

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#8.9 A reinforced earth retaing wall Fig 8.29 is to be 10m high. Here:

Backfill: $\gamma_1 = 16\,kN/m^3$ & $\phi_1' = 34°$

Reinforcement: vertical spacing, $S_V = 1m$
horizontal spacing, $S_H = 1.25m$
width of re-inforcement = 120mm
$f_y = 260\,MN/m^2$, $\phi_u = 25°$
FS against tie pullout = 3
FS against tie breakage = 3

From Prob#8.8

a) tie thickness (No surcharge)

$$\sigma_a' = K_a \gamma_1 z = \tan^2\left(45° - \frac{34°}{2}\right)(16\,kN/m^3)(10m)$$

$$\sigma_a' = 45.23\,kN/m^2$$

[8.39] $$FS_B = \frac{w t f_y}{\sigma_a' S_V S_H} \therefore t = \frac{(FS_B)(\sigma_a' S_V S_H)}{w\, f_y}$$

$$t = \frac{(3)(45.23\,kN/m^2)(1m)(1.25m)}{(0.12m)(260{,}000\,kN/m^2)} = 0.0544\,m \text{ or } \boxed{54.4\,mm}$$

b) max length of ties

$$\sigma_o' = \gamma_1 z = (16\,kN/m^3)(10m) = 160\,kN/m^2$$

[8.42] $$FS_{(P)} = \frac{2\, l_e\, w\, \sigma_o' \tan\phi_u}{\sigma_a' S_V S_H} \therefore l_e = \frac{FS_{(P)}(\sigma_a' S_V S_H)}{2 w \sigma_o' \tan\phi_u}$$

$$l_e = \frac{(3)(45.23\,kN/m^2)(1m)(1.25m)}{(2)(0.12m)(160\,kN/m^2)(\tan(25°))} = 9.47m$$

$$l_r = \frac{H - z}{\tan\left(45 + \frac{\phi_1'}{2}\right)} = \frac{10m - 0}{\tan\left(45 + \frac{34}{2}\right)} = 5.32m$$

$$L = l_e + l_r = 9.47 + 5.32 = \boxed{14.79m}$$

#8.9 Continued

Now #8.9 For in situ soil $\phi'_2 = 25°$, $\gamma_2 = 15.5 kN/m^3$

$c'_2 = 30 kN/m^2$

Calculate the FS against (a) overturning, (b) sliding (c) bearing capacity failure using answer b in Prob 8.8.

a) no surcharge in Prob 8.8 (pg 420)

Table for different depth for L

$l_e = 9.47m$

Z(m)	Tie length L(m)
2	13.72 ≈ 14 m
4	12.66
6	11.60
8	10.53
10	9.47

$L = l_e + \left(\frac{H - z}{\tan 45 + \frac{\phi'}{2}}\right)$

$W_1 = \gamma_1 H L = (16 kN/m^3)(10m)(14m) = 2240 \ kN/m$

$x_1 = \frac{1}{2}(14) = 7m$

$P_a = \frac{1}{2}\gamma K_a H^2 = \frac{1}{2}(16kN/m^3)(0.2543)(10m)^2 = 203.44 \ kN$

P_a acts @ $H/3 = 10/3 = 3.33m = z'$

[8.50] $FS_{(overturning)} = \frac{W_1 x_1}{\left[\int_0^H \sigma'_a \, dz\right] z'} = \frac{(2240)(7m)}{(203.44)(3.33)} = \boxed{23.14}$

b) assume $k = \left(\frac{2}{3}\right)$

[8.51] $FS_{(SLIDING)} = \frac{W_1 \tan(k\phi'_1)}{P_a} = \frac{(2240)\tan\left(\frac{2}{3}(34)\right)}{203.44} = \boxed{4.60}$

8.9 cont.

		N_c	N_q	N_γ
c)	Tbl 3.3 for $\phi'_2 = 25°$	20.72	10.66	10.88

[8.52] $q_u = c'_2 N_c + \frac{1}{2}\gamma_2 L_2 N_\gamma$

$= (30\,kN/m^2)(20.72) + \frac{1}{2}(15.5\,kN/m^3)(14)(10.88)$

$q_u = 1802.8\ kN/m^2$

[8.53] $\sigma'_{o(H)} = \gamma_1 H = (16\,kN/m^3)(10\,m) = 160\ kN/m^2$

[8.54] $FS_{(bearing)} = \dfrac{q_u}{\sigma'_{o(H)}} = \dfrac{1802.8}{160} = \boxed{11.26}$