

For Problems 13.1–13.3, use unit weight of concrete, $\gamma_c = 23.5 \text{ kN/m}^3$. Also assume $k_1 = k_2 = \frac{2}{3}$ in Eq. (13.13).

13.1 For the cantilever retaining wall shown in Figure 13.28, the wall dimensions are $H = 7 \text{ m}$, $x_1 = 0.35 \text{ m}$, $x_2 = 0.65 \text{ m}$, $x_3 = 1.25 \text{ m}$, $x_4 = 3.5 \text{ m}$, $x_5 = 0.9 \text{ m}$, $D = 1.5 \text{ m}$, and $\alpha = 10^\circ$; and the soil properties are $\gamma_1 = 16 \text{ kN/m}^3$, $\phi_1' = 30^\circ$, $\gamma_2 = 18 \text{ kN/m}^3$, $\phi_2' = 28^\circ$, and $c_2' = 25 \text{ kN/m}^2$. Calculate the factors of safety with respect to overturning, sliding, and bearing capacity.

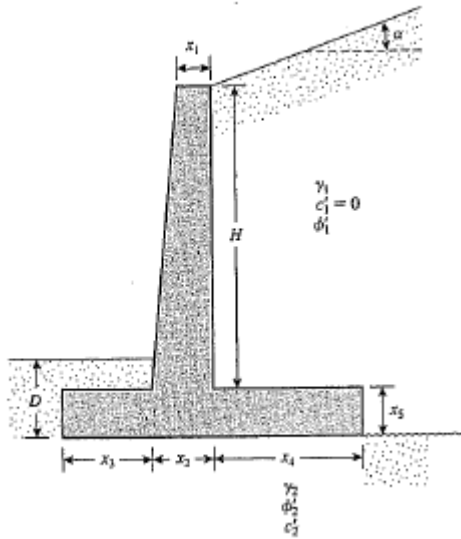


Figure P8.1

13.1 Refer to the diagram. From Table 11.2, $K_a = 0.35$.

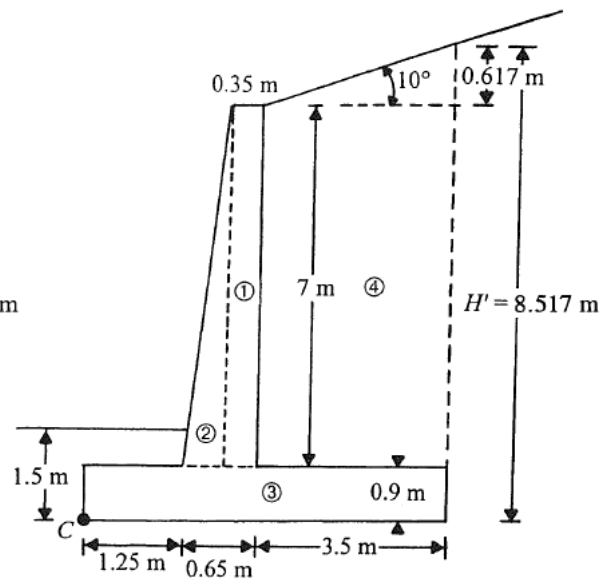
$$\begin{aligned}
 P_a &= \frac{1}{2}(H')^2 \gamma_1 K_a \\
 &= \frac{1}{2}(8.517)^2 (15)(0.35) \\
 &\approx 203 \text{ kN/m}^2
 \end{aligned}$$

$$P_v = P_a \sin 10 = 35.25 \text{ kN/m}$$

$$P_h = P_a \cos 10 = 199.92 \text{ kN/m}$$

Refer to the table.

Note: $\gamma_c = 23.5 \text{ kN/m}^3$



Section	Weight (kN / m)	Moment arm from C (m)	Moment about C (kN - m / m)
1	$(7)(0.35)(\gamma_c) = 57.58$	1.725	99.3
2	$(0.5)(0.3)(7)(\gamma_c) = 24.68$	1.45	35.8
3	$(5.4)(0.9)(\gamma_c) = 114.21$	2.7	308.4
4	$\frac{7 + 8.517}{2}(3.5)(16) = 409.28$	$1.25 + 0.65 + 1.75 = 3.65$	1493.87
	$P_v = 35.25$	5.4	190.35
	$\Sigma 641$		$\Sigma 2127.72$

$$M_o = P_h \frac{H'}{3} = \frac{(199.92)(8.517)}{3} = 567.6 \text{ kN} \cdot \text{m} / \text{m}$$

$$FS_{(\text{overturning})} = \frac{2127.72}{567.6} = 3.75$$

$$FS_{(\text{sliding})} = \frac{\sum V \tan\left(\frac{2}{3}\phi'_2\right) + B\left(\frac{2}{3}\right)c'_2}{P_a \cos \alpha} = \frac{(641) \tan\left[\left(\frac{2}{3}\right)(28)\right] + (54)\left[\left(\frac{2}{3}\right)(25)\right]}{199.92}$$

$$= 1.53$$

$$e = \frac{B}{2} - \frac{\sum M_R - \sum M_o}{\sum V} = 2.7 - \frac{2127.72 - 567.6}{641} = 0.266 \text{ m}$$

$$q_{\text{toc}} = \frac{\sum V}{B} \left(1 + \frac{6e}{B}\right) = \frac{641}{5.4} \left[1 + \frac{(6)(0.266)}{5.4}\right] = 153.79 \text{ kN} / \text{m}^2$$

$$B' = B - 2e = 5.4 - (2)(0.266) = 4.87 \text{ m}$$

$$q_u = c'_2 N_c F_{cd} F_{ci} + q N_q F_{qd} F_{qi} + \frac{1}{2} \gamma_2 B' N_\gamma F_{\gamma d} F_{\gamma i}$$

For $\phi'_2 = 28^\circ$, $N_c = 25.8$; $N_q = 14.72$; $N_\gamma = 16.72$ (Table 12.1)

$$F_{cd} = 1 + 0.4 \left(\frac{D_f}{B'}\right) = 1 + 0.4 \left(\frac{1.5}{4.87}\right) = 1.123$$

$$\psi = \tan^{-1} \left(\frac{P_a \cos \alpha}{\sum V}\right) = \tan^{-1} \left(\frac{199.92}{641}\right) = 17.3^\circ$$

$$F_{qi} = F_{ci} = \left(1 - \frac{\psi}{90}\right)^2 = \left(1 - \frac{17.3}{90}\right)^2 = 0.65$$

$$q = 1.5 \gamma_2 = (1.5)(18) = 27 \text{ kN} / \text{m}^2$$

$$F_{qd} = 1 + 0.299 \left(\frac{1.5}{4.87}\right) = 1.092$$

$$F_{\gamma i} = \left(1 - \frac{\psi}{\phi'_2}\right) = \left(1 - \frac{17.3}{28}\right) = 0.146; \quad F_{\gamma d} = 1$$

$$q_u = (25)(25.8)(1.123)(0.65) + (27)(14.72)(1.092)(0.65) + \frac{1}{2}(18)(4.87)(16.72)(1)(0.146)$$

$$= 859.89 \text{ kN} / \text{m}^2$$

$$FS_{(\text{bearing})} = \frac{q_u}{q_{\text{toc}}} = \frac{859.89}{153.79} = 5.59$$

8.4 A gravity retaining wall is shown in Figure P8.4. Calculate the factor of safety with respect to overturning and sliding, given the following data:

Wall dimensions: $H = 6$ m, $x_1 = 0.6$ m, $x_2 = 2$ m, $x_3 = 2$ m, $x_4 = 0.5$ m, $x_5 = 0.75$ m, $x_6 = 0.8$ m, $D = 1.5$ m

Soil properties: $\gamma_1 = 16.5$ kN/m³, $\phi_1' = 32^\circ$, $\gamma_2 = 18$ kN/m³, $\phi_2' = 22^\circ$, $c_2' = 40$ kN/m²

Use the Rankine active earth pressure in your calculation.

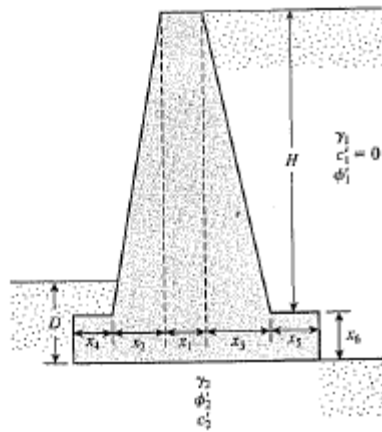


Figure P8.4

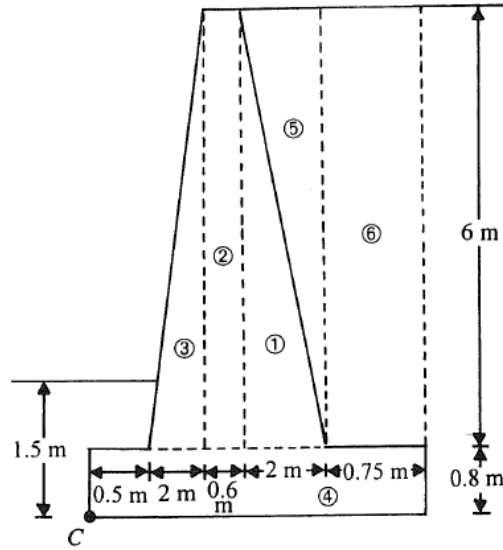
13.4 Refer to the figure. $H' = 6.8 \text{ m}$; $\phi'_1 = 32^\circ$

$$K_a = \tan^2\left(45 - \frac{32}{2}\right) = 0.307$$

$$\begin{aligned} P_o = P_h &= \frac{1}{2}(H')^2 \gamma_1 K_a \\ &= \frac{1}{2}(6.8)^2 (16.5)(0.307) \\ &= 117.1 \text{ kN/m}^2 \end{aligned}$$

Refer to the table.

Note: $\gamma_c = 23.58 \text{ kN/m}^3$



Section	Weight (kN/m)	Moment arm from C (m)	Moment about C (kN - m/m)
1	$(0.5)(2)(6)(\gamma_c) = 141.48$	3.77	533.38
2	$(0.6)(6)(\gamma_c) = 84.89$	2.8	237.69
3	$(0.5)(2)(6)(\gamma_c) = 141.48$	1.83	258.9
4	$(5.85)(0.8)(\gamma_c) = 110.35$	2.925	322.77
5	$(0.5)(6)(2)(16.5) = 99.00$	4.43	438.57
6	$(0.75)(6)(16.5) = 74.25$	5.475	406.52
	$\Sigma 651.45$		$\Sigma 2197.83$

$$M_o = P_h \frac{H'}{3} = (117.1) \left(\frac{6.8}{3}\right) = 265.4 \text{ kN - m/m}$$

$$FS_{(\text{overturning})} = \frac{\Sigma M_R}{\Sigma M_o} = \frac{2197.83}{265.4} = 8.28$$

$$FS_{(\text{sliding})} = \frac{\Sigma V \tan\left(\frac{2}{3} \phi'_2\right) + B \left(\frac{2}{3}\right) c'_2}{P_o \cos \alpha} = \frac{(651.45) \tan(14.66) + (585) \left[\left(\frac{2}{3}\right)(40)\right]}{117.1} = 2.79$$