where

$$A_1' = \frac{p_5}{\gamma(K_p - K_a)} \quad (8.32)$$

$$A_2' = \frac{8P}{\gamma(K_p - K_a)} \quad (8.33)$$

$$A_3' = \frac{6P[2\bar{z}\gamma(K_p - K_a) + p_5]}{\gamma^2(K_p - K_a)^2} \quad (8.34)$$

$$A_4' = \frac{P(6\bar{z}p_5 + 4P)}{\gamma^2(K_p - K_a)^2} \quad (8.35)$$

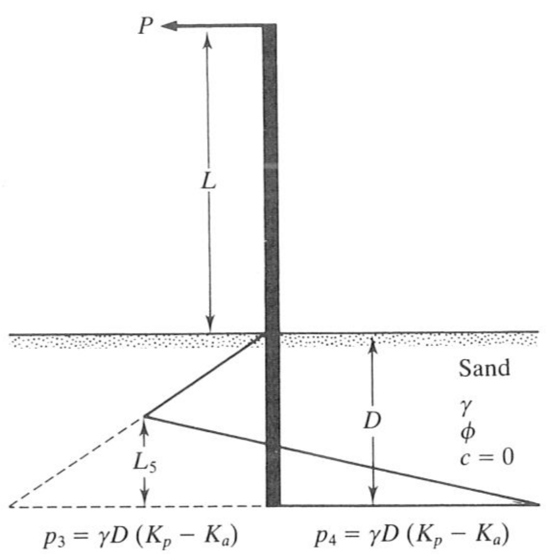
Case 2: Free Cantilever Sheet Piling

Figure 8.10 shows a free cantilever sheet pile wall penetrating a sandy soil and subjected to a line load of P per unit length of the wall. For this case,

$$D^4 - \left[\frac{8P}{\gamma(K_p - K_a)}\right]D^2 - \left[\frac{12PL}{\gamma(K_p - K_a)}\right]D - \left[\frac{2P}{\gamma(K_p - K_a)}\right]^2 = 0 \quad (8.36)$$

and

$$L_5 = \frac{\gamma(K_p - K_a)D^2 - 2P}{2D(K_p - K_a)\gamma} \quad (8.37)$$



▼ FIGURE 8.10 Free cantilever sheet piling penetrating a sand layer

$$M_{max} = P(L + z') - \frac{\gamma z'^3(K_p - K_a)}{6} \quad (8.38)$$

$$z' = \sqrt{\frac{2P}{\gamma'(K_p - K_a)}} \quad (8.39)$$

▼ EXAMPLE 8.2

Redo Parts a and b of Example 8.1 assuming the absence of the water table. Use $\gamma = 15.9\ \text{kN/m}^3$ and $\phi = 32°$. Note: $L = 5$ m.

Solution

Part a

Quantity required	Eq. no.	Equation and calculation
K_a	—	$\tan^2\left(45 - \frac{\phi}{2}\right) = \tan^2\left(45 - \frac{32}{2}\right) = 0.307$
K_p	—	$\tan^2\left(45 + \frac{\phi}{2}\right) = \tan^2\left(45 + \frac{32}{2}\right) = 3.25$
p_2	8.24	$\gamma L K_a = (15.9)(5)(0.307) = 24.41\ \text{kN/m}^2$
L_3	8.28	$\frac{LK_a}{K_p - K_a} = \frac{(5)(0.307)}{3.25 - 0.307} = 0.521$ m
p_5	8.27	$\gamma L K_p + \gamma L_3(K_p - K_a) = (15.9)(5)(3.25) + (15.9)(0.521)(3.25 - 0.307) = 282.76\ \text{kN/m}^2$
P	8.29	$\frac{1}{2}p_2 L + \frac{1}{2}p_2 L_3 = \frac{1}{2}p_2(L + L_3) = (\frac{1}{2})(24.41)(5 + 0.521) = 67.38$ kN/m
$\bar{z}$	8.30	$\frac{L(2K_a - K_p)}{3(K_p - K_a)} = \frac{5[(2)(0.307) + 3.25]}{3(3.25 - 0.307)} = 2.188$ m
A_1'	8.32	$\frac{p_5}{\gamma(K_p - K_a)} = \frac{282.76}{(15.9)(3.25 - 0.307)} = 6.04$
A_2'	8.33	$\frac{8P}{\gamma(K_p - K_a)} = \frac{(8)(67.38)}{(15.9)(3.25 - 0.307)} = 11.52$
A_3'	8.34	$\frac{6P[2\bar{z}\gamma(K_p - K_a) + p_5]}{\gamma^2(K_p - K_a)^2} = \frac{(6)(67.38)[(2)(2.188)(15.9)(3.25 - 0.307) + 282.76]}{(15.9)^2(3.25 - 0.307)^2} = 90.01$
A_4'	8.35	$\frac{P(6\bar{z}p_5 + 4P)}{\gamma^2(K_p - K_a)^2} = \frac{(67.38)[(6)(2.188)(282.76) + (4)(67.38)]}{(15.9)^2(3.25 - 0.307)^2} = 122.52$
L_4	8.31	$L_4^4 + A_1'L_4^3 - A_2'L_4^2 - A_3'L_4 - A_4' = 0$; $L_4^4 + 6.04L_4^3 - 11.52L_4^2 - 90.01L_4 - 122.52 = 0$; $L_4 \approx 4.1$ m

$$D_{\text{theory}} = L_3 + L_4 = 0.521 + 4.1 = \mathbf{4.7\ m}$$

Part b

Total length, $L + 1.3(D_{\text{theory}}) = 5 + 1.3(4.7) = \mathbf{11.11\ m}$ ▲

▼ EXAMPLE 8.3

Refer to Figure 8.10. For $L = 15$ ft, $\gamma = 110$ lb/ft^3, $\phi = 30°$, and $P = 2000$ lb/ft, determine:

a. The theoretical depth of penetration, D
b. The maximum moment, $M_{\max}$ (lb-ft/ft)

Solution

$$K_p = \tan^2\left(45 + \frac{\phi}{2}\right) = \tan^2\left(45 + \frac{30}{2}\right) = 3$$

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right) = \tan^2\left(45 - \frac{30}{2}\right) = \frac{1}{3}$$

$$K_p - K_a = 3 - 0.333 = 2.667$$

Part a

From Eq. (8.36),

$$D^4 - \left[\frac{8P}{\gamma(K_p - K_a)}\right]D^2 - \left[\frac{12PL}{\gamma(K_p - K_a)}\right]D - \left[\frac{2P}{\gamma(K_p - K_a)}\right]^2 = 0$$

and

$$\frac{8P}{\gamma(K_p - K_a)} = \frac{(8)(2000)}{(110)(2.667)} = 54.54$$

$$\frac{12PL}{\gamma(K_p - K_a)} = \frac{(12)(2000)(15)}{(110)(2.667)} = 1227.1$$

$$\frac{2P}{\gamma(K_p - K_a)} = \frac{(2)(2000)}{(110)(2.667)} = 13.63$$

so

$$D^4 - 54.54D^2 - 1227.1D - (13.63)^2 = 0$$

From the preceding equation, $D \approx$ **12.5 ft**

Part b

From Eq. (8.39),

$$z' = \sqrt{\frac{2P}{\gamma(K_p - K_a)}} = \sqrt{\frac{(2)(2000)}{(110)(2.667)}} = 3.69 \text{ ft}$$

From Eq. (8.38),

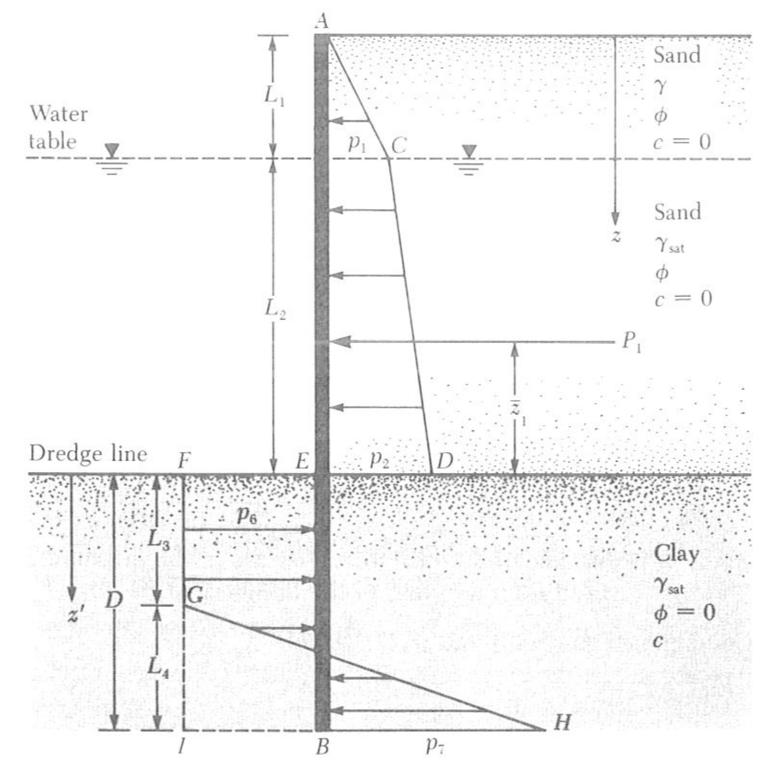
$$M_{\max} = P(L + z') - \frac{\gamma z'^3(K_p - K_a)}{6}$$

$$= (2000)(15 + 3.69) - \frac{(110)(3.69)^3(2.667)}{6}$$

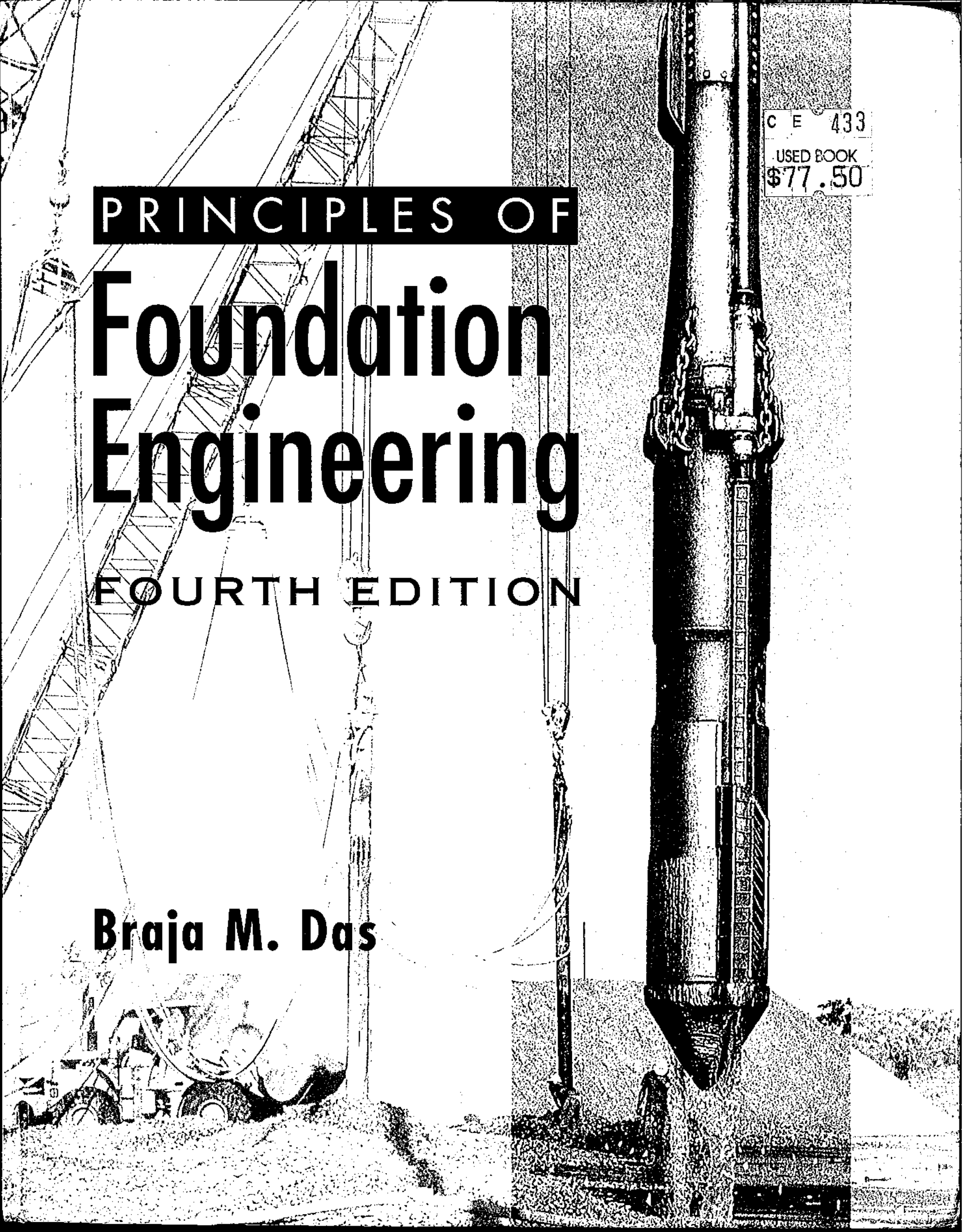
$$= 37{,}380 - 2456.65 \approx \mathbf{34{,}923\ lb\text{-}ft/ft}$$ ▲

8.6 CANTILEVER SHEET PILING PENETRATING CLAY

At times, cantilever sheet piles must be driven into a clay layer possessing an undrained cohesion, c ($\phi = 0$ concept). The net pressure diagram will be somewhat different from that shown in Figure 8.7a. Figure 8.11 shows a cantilever sheet pile wall driven into clay with a backfill of granular soil above the level of the dredge line. The water table is at depth L_1 below the top of the wall. As before, Eqs. (8.1) and (8.2) give the intensity of the net pressures p_1 and p_2, and the diagram for pressure distribution above the level of the dredge line can be drawn. The diagram for net pressure distribution below the dredge line can now be determined as follows.



▼ FIGURE 8.11 Cantilever sheet pile penetrating clay



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