Chapter 9

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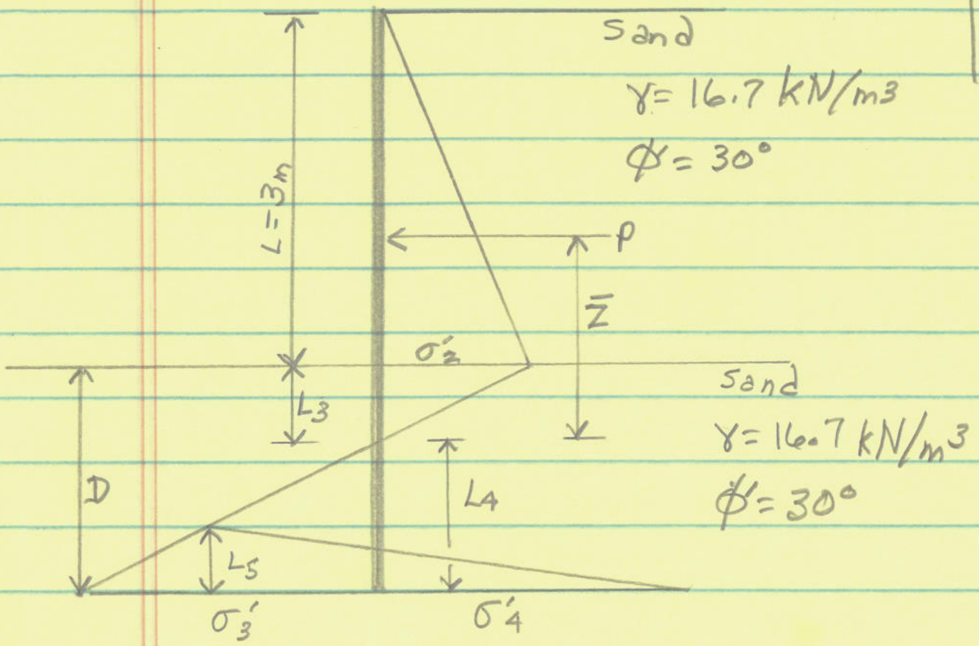
ENCE 43

#9.3 Given:



Required: Calculate the theoritical depth of penetration D & the maximum moment.

a) $K_a = \tan^2(45 - \frac{\phi'}{2}) = \tan^2(45° - \frac{30°}{2}) = 0.33$

$K_p = \tan^2(45 + \frac{\phi'}{2} = \tan^2(45° + \frac{30°}{2}) = 3.00$

[9.24] $\sigma'_2 = \gamma L k_a = (16.7)(3)(0.33) = 16.53\ kN/m^2$

[9.28] $L_3 = \frac{L K_a}{k_p - k_a} = \frac{(3)(0.33)}{3 - 0.33} = 0.371\ m$

[9.27] $\sigma'_5 = \gamma L k_p + \gamma L_3 (k_p - k_a)$

$= (16.7)(3)(3) + (16.7)(0.371)(3 - 0.333)$

– $\sigma'_5 = 166.84\ kN/m^2$

[9.29] $P = \frac{1}{2}\sigma'_2 L + \frac{1}{2}\sigma'_2 L_3$

$P = \frac{1}{2}(16.53)(3) + \frac{1}{2}(16.53)(0.371)$

$P = 27.86\ kN/m$

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#9.3 Cont.

[9.30] $\bar{z} = \frac{L(2k_a + k_p)}{3(k_p - k_a)} = \frac{3[2(0.33)+3]}{3(3-0.33)} = 1.37m$

[9.32] $A'_1 = \frac{\sigma'_5}{\gamma(k_p - k_a)} = \frac{166.84}{(16.7)(3-0.33)} = 3.74\ m^2$

[9.33] $A'_2 = \frac{8P}{\gamma(k_p - k_a)} = \frac{(8)(27.86)}{(16.7)(3-0.33)} = 5.00\ m^2$

[9.34] $A'_3 = \frac{6P[2\bar{z}\gamma(k_p - k_a) + \sigma'_5]}{\gamma^2(k_p - k_a)^2}$

$= \frac{6(27.86)[(2)(1.37)(16.7)(3-0.33)+166.84]}{(16.7)^2(3-0.33)^2}$

$A'_3 = 23.75\ m^2$

[9.35] $A'_4 = \frac{P(6\bar{z}\sigma'_5 + 4P)}{\gamma^2(k_p - k_a)^2}$

$= \frac{(27.86)[(6)(1.37)(166.84) + 4(27.86)]}{16.7^2(3-0.33)^2}$

$= 20.83\ m^2$

[9.31] $L_4: L_4^4 + A'_1 L_4^3 - A'_2 L_4^2 - A'_3 L_4 - A'_4 = 0$

$L_4^4 + 3.74 L_4^3 - 5 L_4^2 - 23.75 L_4 - 20.83 = 0$

$L_4 = 2.65\ m$

→ $D_{theory} = L_3 + L_4 = 0.371 + 2.65 = \boxed{3.02\ m}$

$z' = \sqrt{\frac{2P}{\gamma(k_p - k_a)}} = \sqrt{\frac{2(27.86)}{(16.7)(3-0.33)}} = 1.12m$

Next ↓

#9.3 Continued

$$M_{max} = P(\bar{z} + z') - \left[\tfrac{1}{2}\gamma z'^2 (k_p - k_a)\right]\tfrac{1}{3}z'$$

$$= (27.86)(1.37 + 1.12) - \left[\tfrac{1}{2}(16.7)(1.12)^2(3 - 0.33)\right]\tfrac{1}{3}(1.12)$$

$$= 58.81 \text{ kN-m/m}$$

#9.7 assume $D_{actual} = 1.3\ D_{theroy}$

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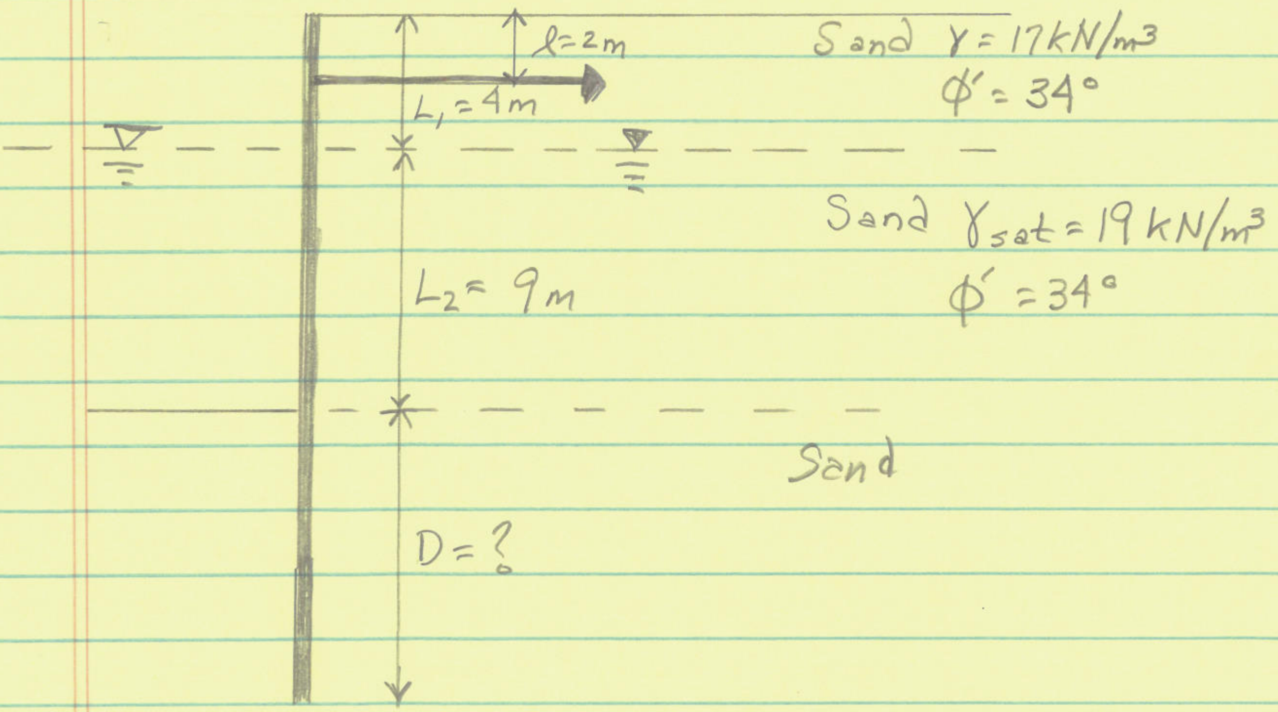
#9.6 An anchored sheet pile bulkhead is shown below $L_1 = 4m$, $L_2 = 9m$, $l_1 = 2m$, $\gamma = 17 kN/m^3$, $\gamma_{sat} = 19 kN/m^3$ & $\phi' = 34°$

a) calculate D_{theory}

#9.7

b) Determine the theorectical maximum moment

c) Use Rowe's moment reduction techique, Choose a sheet pile section. Take $E = 210 \times 10^3\ MN/m^2$ & $\sigma_{all} = 210,000\ kN/m^2$



\#9.7 Cont.

$$K_a = \tan^2\left(45-\frac{\phi'}{2}\right) = \tan^2\left(45-\overset{17}{\frac{34}{2}}\right) = 0.283$$

$$K_p = \tan^2\left(45+\frac{\phi'}{2}\right) = \tan^2\left(45+\frac{34}{2}\right) = 3.537$$

$$K_p - K_a = 3.537 - 0.283 = 3.254$$

$$\gamma' = \gamma_{sat} - \gamma_w = 19 - 9.81 = 9.19\ kN/m^3$$

$$[9.1]\quad \sigma_1' = \gamma L_1 K_a = (17)(4)(0.283) = 19.24\ kN/m^2$$

$$[9.2]\quad \sigma_2' = (\gamma L_1 + \gamma' L_2)K_a = [(17\times4)+(9.19\times9)]0.283 = 42.65\ kN/m^2$$

$$[9.6]\quad L_3 = \frac{\sigma_2'}{\gamma'(K_p-K_a)} = \frac{42.65}{9.19(3.254)} = 1.42\,m$$

$$P = \tfrac{1}{2}\sigma_1' L_1 + \sigma_2' L_2 + \tfrac{1}{2}(\sigma_2'-\sigma_1')L_2 + \tfrac{1}{2}\sigma_2' L_3$$

$$= \tfrac{1}{2}(19.24)(4m) + (42.65)(9) + \tfrac{1}{2}(42.65-19.24)(9) + \tfrac{1}{2}(42.65)(1.42)$$

$$P = 38.48 + 383.85 + 105.35 + 30.28 = 557.96$$

$$\bar{z} = \frac{\Sigma M_E}{P} = \left[\begin{array}{l} 38.48\left(1.42+9+\frac{4}{3}\right) + 383.85\left(1.42+\frac{9}{2}\right) \\ + 105.35\left(1.42+\frac{9}{3}\right) + 30.28\left(\frac{2\times1.42}{3}\right) \end{array}\right] \times \frac{1}{557.9}$$

$$\bar{z} = \frac{[452.268 + 2272.392 + 465.647 + 28.665]}{557.96}$$

$$\bar{z} = 5.77\,m$$

$$[9.67]\quad L_4:\ L_4^3 + 1.5L_4^2(l_2+L_2+L_3) - \frac{3P[(L_1+L_2+L_3)-(\bar{z}+l_1)]}{\gamma'(K_p-K_a)} = 0$$

$$L_4^3 + 1.5L_4^2(2+9+1.42) - \frac{3P[(4+9+1.42)-(5.77+2)]}{9.19(3.254)} = 0$$

$$L_4 = 4.05\,m$$

Next ↓

9.7 Cont

$D_{theory} = L_3 + L_4 = 1.42 + 4.05 = \boxed{5.47}\, m$

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b) $D_{ACTUAL} = 1.3 D_{theory} = 1.3(5.47) = \boxed{7.11 m}$

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c) Anchor Force

$F = P - \frac{1}{2}\gamma'(k_P - k_a)L_4^2$

$= 577.96 - \frac{1}{2}(9.19)(3.254)(4.05)^2 = 332.71\, kN/m$

Max moment

[9.69] $\frac{1}{2}\sigma_1' L_1 - F + \sigma_1'(z - L_1) + \frac{1}{2}k_a\gamma'(z - L_1)^2 = 0$

Let $(z-1) = x$ ∴

$\frac{1}{2}\sigma_1' l_1 - F + \sigma_1'(x) + \frac{1}{2}K_a\gamma' x^2 = 0$

$\frac{1}{2}(19.24)(2) - 332.71 + (19.24x) + \frac{1}{2}(0.283)(9.19)x^2 = 0$

$1.30x^2 + 19.24x - 313.47 = 0$

$x = 9.80$

$z = x + L_1 = 9.80 + 4 = 13.80\, m$

$M_{max} = \frac{1}{2}\sigma_1' L_1\left(x + \frac{L_1}{3}\right) + F(x + l_2) - \sigma_1'\frac{x^2}{2} - \frac{1}{2}K_a\gamma' x^2\left(\frac{x}{3}\right)$

$= \frac{1}{2}(19.24)(4)\left(9.8 + \frac{4}{3}\right) + 332.71(9.8 + 2)$

$- (19.24)\frac{9.8^2}{2} - \frac{1}{2}(0.283)(9.19)(9.8)^2\left(\frac{9.8}{3}\right)$

$= 428.41 + 3925.98 - 923.9 - 407.97$

$M_{max} = 3022.52\, kN \cdot m/M$

9.7 Cont

c) $\boxed{\text{Using Free Earth Support Method}}$

Fig 9.19 $\frac{l_1}{L_1+L_2} = \frac{2m}{13m} = 0.154$ & $\phi' = 34°$

$\boxed{GF \approx 0.06}$

Fig 9.22 $\frac{L_1}{L_1+L_2} = \frac{4}{3} = 0.31$ $\boxed{CFL \approx 1.68}$

$$[9.73] \quad \gamma_a = \frac{\gamma L_1^2 + \gamma' L_2^2 + 2\gamma L_1 L_2}{(L_1+L_2)^2}$$

$$\gamma_a = \frac{(17)4^2 + (9.19)9^2 + 2(17)(4)(9)}{(4+9)^2} = \boxed{13.26 \text{ kN/m}^3}$$

$$[9.71] \quad F = \gamma_a (L_1+L_2)^2 (GF)(CFL)$$

$$F = (13.3)(4+9)^2(0.06)(1.68) = \boxed{226.6 \text{ kN/m}}$$

Max moment

Fig 9.20 $\frac{l_1}{L_1+L_2} = 0.154$ & $\phi' = 34°$ $GM = 0.018$

Fig 9.23 $\frac{L_1}{L_1+L_2} = 0.31$ $CML = 1.08$

$$[9.72] \quad M_{max} = \gamma_a (L_1+L_2)^3 (GM)(CML)$$

$$= (13.26)(4+9)^3(0.018)(1.08)$$

$$\boxed{= 566.33 \text{ kN}\cdot\text{m/m}}$$

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9.7 Cont

Use Rowe's moment reduction diagram

Fig 9.24 $E = 210 \times 10^3 \ MN/m^2$

& $\sigma_{all} = 210{,}000 \ kN/m^2$

$H' = L_1 + L_2 + D_{actual} = 4 + 9 + 7.11 = 20.11 m$

$M_{max} = 566.33 \ kN \cdot m/m$

[9.74a] $e = 10.91 \times 10^{-7} \left(\frac{H'^4}{EI} \right)$

Section	I	H'	e	log e	S	Md	$\frac{M_d}{M_{ma}}$
PZ27	251.5×10^{-6}	20.11	3.378×10^{-3}	-2.47	162.3×10^{-5}	340.8	0.601
PZ35	493.4×10^{-6}	20.11	1.722×10^{-3}	-2.76	260.5×10^{-5}	547.1	0.966

$\boxed{\text{Use PZ35}}$

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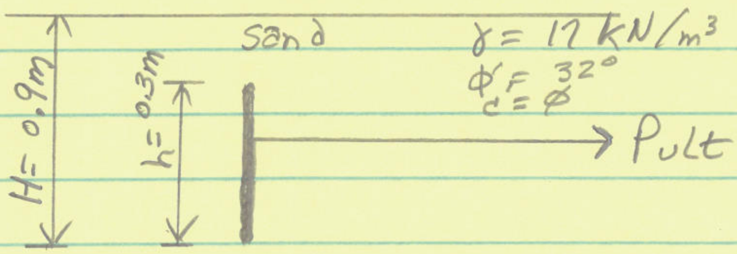
#9.12

A single anchor slab shown below. $H = 0.9m$, $h = 0.3m$ $\gamma = 17 kN/m^3$ & $\phi' = 32°$. Calculate the ultimate holding capacity of the anchor slab if the width B is

a) 0.3m b) 0.6m c) 0.9m

(Note center to center spacing $S' = \infty$. Use empirical correlation [9.94]



[9.94] a) $$P_{ult} = \frac{5.4}{\tan\phi'}\left(\frac{H^2}{A}\right)^{0.28}\gamma A H$$

$$= \frac{5.4}{\tan 32}\left(\frac{0.9^2}{0.09}\right)^{0.28}(17)(0.09)(0.9)$$

$$\boxed{P_{ult} = 22.01\ kN}$$

$B = 0.3m$
$A = Bh = (0.3)(0.3)$
$A = 0.09\ m^2$

b) $$P_{ult} = \frac{5.4}{\tan 32°}\left(\frac{0.9^2}{0.18}\right)^{0.28}(17)(0.18)(0.9)$$

$$\boxed{P_{ult} = 36.26\ kN}$$

$B = 0.6m$
$A = 0.3 \times 0.6 = 0.18$

c) $$P_{ult} = \frac{5.4}{\tan 32°}\left(\frac{0.9^2}{0.27}\right)^{0.28}(17)(0.27)(0.9)$$

$$\boxed{P_{ult} = 48.56\ kN}$$

$B = 0.9$
$A = (0.3)(0.9) = 0.2$