Cantilever sheet pile wall in clay

At times, cantilever sheet piles must be driven into a clay layer possessing an undrained cohesion The net pressure diagram will be somewhat different. Fig.1 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 a depth L_1 below the top of the wall. As before the intensity of the net pressures σ_1 and σ_2 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.

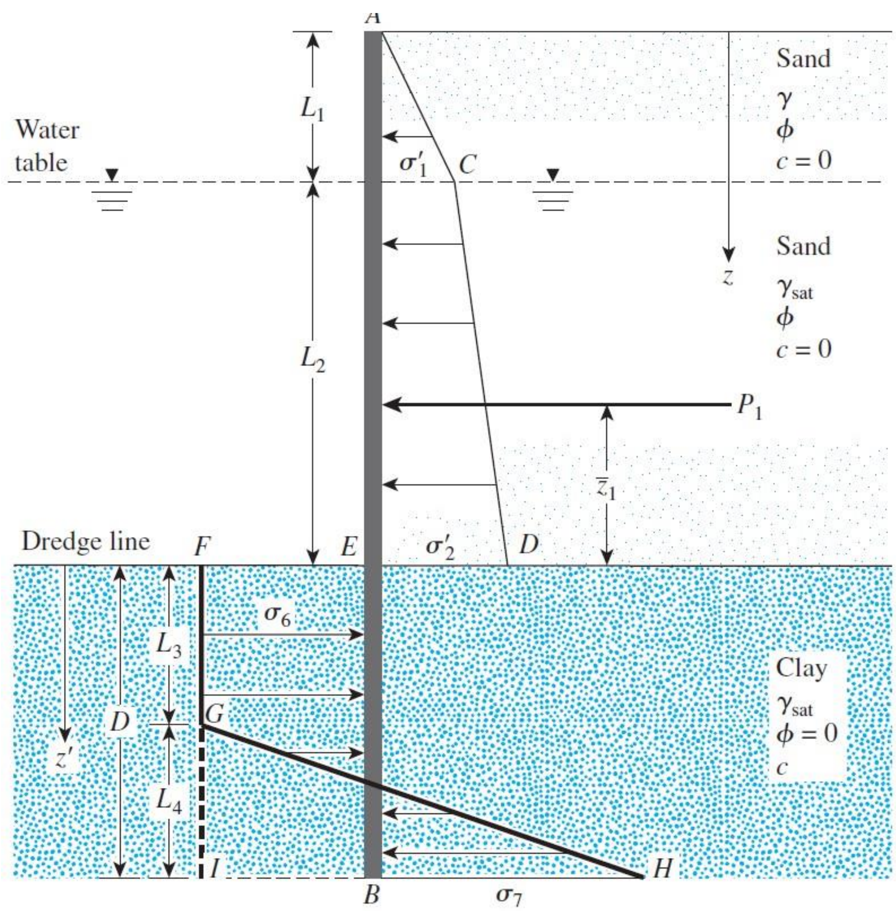

Fig.1

At any depth greater $(L_1 + L_2)$than for $\emptyset = 0$ the Rankine active earth-pressure coefficient $k_a = 1$ Similarly, for $\emptyset = 0$ the Rankine passive earth-pressure coefficient $K_p = 1$, Thus, the active pressure, from right to left is

$$\sigma_a = (\gamma L_1 + \gamma' L_2) + \gamma_{sat}(Z - L_1 + L_2) - 2C$$

Similarly, the passive pressure from left to right may be expressed as

$$\sigma_p = \gamma_{sat}(z - L_1 - L_2) + 2C$$

Thus the net pressure is:

$$\sigma = \sigma_p - \sigma_a = \gamma_{sat}(z - L_1 - L_2) + 2C - [(\gamma L_1 + \gamma' L_2) + \gamma_{sat}(Z - L_1 + L_2) - 2C]$$

$$\sigma = 4C - (\gamma L_1 + \gamma' L_2)$$

At the bottom of the sheet pile, the passive pressure from right to left is

$$\boldsymbol{\sigma_p = (\gamma L_1 + \gamma' L_2) + \gamma_{sat} D + 2C}$$

$$\boldsymbol{\sigma_a = \gamma_{sat} D - 2C}$$

Hence, the net pressure is

$$\boldsymbol{\sigma_7 = \sigma_p - \sigma_a = (\gamma L_1 + \gamma' L_2) + \gamma_{sat} D + 2C - [\gamma_{sat} D - 2C]}$$

$$\boldsymbol{\sigma_7 = 4C + (\gamma L_1 + \gamma' L_2)}$$

For equilibrium analysis, $\sum H = 0$ that is, the area of the pressure diagram *ACDE* minus the area of *EFIB* plus the area of GIH = 0 or

$$\boldsymbol{P_1 - 4C - (\gamma L_1 + \gamma' L_2) + 4C + \frac{1}{2} L_4[(\gamma L_1 + \gamma' L_2) + 4C + (\gamma L_1 + \gamma' L_2)] = 0}$$

where $P_1 = area$ of the pressure diagram *ACDE.* Simplifying the preceding equation produces

$$\boldsymbol{L_4 = \frac{D[4C - (\gamma L_1 + \gamma' L_2)] - P}{4C}} \quad \textbf{(1)}$$

Now, taking the moment about point *B,* $\sum M_B = 0$ yields

$$\boldsymbol{P_1(\acute{Z} + D) - [4C - (\gamma L_1 + \gamma' L_2)] * \frac{D^2}{2} + \frac{1}{2}(8C) L_4 * \frac{L_4}{3} = 0} \quad \textbf{\textit{(2)}}$$

Combining (1) and (2) yields

$$D^2[4c - (\gamma L_1 + \gamma' L_2)] - 2DP_1 - |\frac{P_1(P_1 + 12c\bar{z}_1)}{(\gamma L_1 + \gamma' L_2) + 2c} = 0 \quad (3)$$

Eq.3 may be solved to obtain *D,* the theoretical depth of penetration of the clay layer by the sheet pile.

Step-by-Step Procedure for Obtaining the Pressure Diagram

Step 1. Calculate k_a for the granular soil (backfill).
Step 2. Obtain σ_1 *and* σ_2 and
Step 3. Calculate P1 and Ź
Step 4. obtain the theoretical value of *D.*
Step 5. Calculate L4
Step 6. Calculate σ_6 and σ_7

Step 7. Draw the pressure distribution diagram as shown in Figure 9.1
Step 8. The actual depth of penetration is

$$D_{actual} = 1.4\ to\ 1.6\ D_{theoretical}$$

Maximum bending moment

According to Fig.1 the maximum bending moment (zero shear) is occurred between $L_1 + L_2 < z < L_1 + L_2 + L_3$. Using new coordinate system $z^{'}$(with $z^{'}$ = 0 at the dredge line) for zero shear gives

$$P_1 - \sigma_6 z^{'} = 0$$

$$z^{'} = \frac{P_1}{\sigma_6}$$

$$M_{max} = P_1(\acute{Z} + z^{'}) - \sigma_6 \frac{z^{'2}}{2}$$

Example 9.3

In Figure 9.13, for the sheet pile wall, determine

a. The theoretical and actual depth of penetration. Use $D_{actual} = 1.5 D_{theory}$.
b. The minimum size of sheet pile section necessary. Use $\sigma_{all} = 172.5\ MN/m^2$.

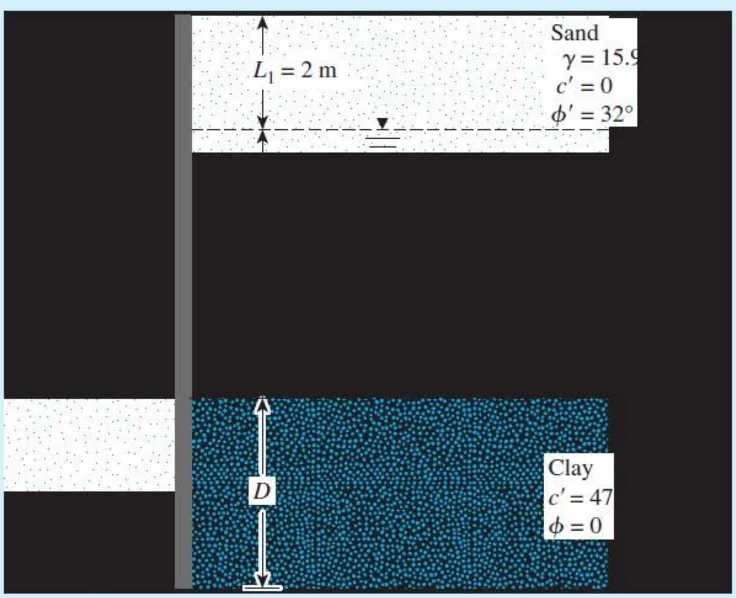

Figure 9.13 Cantilever sheet pile penetrating into saturated clay

We will follow the step-by-step procedure given in Section 9.6:

Step 1.

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

Step 2.

$$\sigma_1' = \gamma L_1 K_a = (15.9)(2)(0.307) = 9.763 \text{ kN/m}^2$$

$$\sigma_2' = (\gamma L_1 + \gamma' L_2) K_a = [(15.9)(2) + (19.33 - 9.81)3]0.307$$
$$= 18.53 \text{ kN/m}^2$$

Step 3. From the net pressure distribution diagram given in Figure 9.12, we have

$$P_1 = \frac{1}{2}\sigma_1' L_1 + \sigma_1' L_2 + \frac{1}{2}(\sigma_2' - \sigma_1') L_2$$
$$= 9.763 + 29.289 + 13.151 = 52.2 \text{ kN/m}$$

and

$$\bar{z}_1 = \frac{1}{52.2}\left[9.763\left(3 + \frac{2}{3}\right) + 29.289\left(\frac{3}{2}\right) + 13.151\left(\frac{3}{3}\right)\right]$$
$$= 1.78 \text{ m}$$

Step 4. From Eq. (9.48),

$$D^2[4c - (\gamma L_1 + \gamma' L_2)] - 2DP_1 - \frac{P_1(P_1 + 12c\bar{z}_1)}{(\gamma L_1 + \gamma' L_2) + 2c} = 0$$

Substituting proper values yields

$$D^2\{(4)(47) - [(2)(15.9) + (19.33 - 9.81)3]\} - 2D(52.2)$$
$$- \frac{52.2[52.2 + (12)(47)(1.78)]}{[(15.9)(2) + (19.33 - 9.81)3] + (2)(47)} = 0$$

or

$$127.64D^2 - 104.4D - 357.15 = 0$$

Solving the preceding equation, we obtain $D = 2.13$ m.

Step 5. From Eq. (9.46),

$$L_4 = \frac{D[4c - (\gamma L_1 + \gamma' L_2)] - P_1}{4c}$$

and

$$4c - (\gamma L_1 + \gamma' L_2) = (4)(47) - [(15.9)(2) + (19.33 - 9.81)3]$$
$$= 127.64 \text{ kN/m}^2$$

So,

$$L_4 = \frac{2.13(127.64) - 52.2}{(4)(47)} = 1.17 \text{ m}$$

Step 6.

$$\sigma_6 = 4c - (\gamma L_1 + \gamma' L_2) = 127.64 \text{ kN/m}^2$$

$$\sigma_7 = 4c + (\gamma L_1 + \gamma' L_2) = 248.36 \text{ kN/m}^2$$

Step 7. The net pressure distribution diagram can now be drawn, as shown in Figure 9.12.

Step 8. $D_{\text{actual}} \approx 1.5 D_{\text{theoretical}} = 1.5(2.13) \approx \mathbf{3.2\ m}$

Maximum-Moment Calculation

From Eq. (9.49),

$$z' = \frac{P_1}{\sigma_6} = \frac{52.2}{127.64} \approx 0.41 \text{ m}$$

Again, from Eq. (9.50),

$$M_{\max} = P_1(z' + \bar{z}_1) - \frac{\sigma_6 z'^2}{2}$$

So

$$M_{\max} = 52.2(0.41 + 1.78) - \frac{127.64(0.41)^2}{2}$$
$$= 114.32 - 10.73 = 103.59 \text{ kN-m/m}$$

The minimum required section modulus (assuming that $\sigma_{\text{all}} = 172.5 \text{ MN/m}^2$) is

$$S = \frac{103.59 \text{ kN-m/m}}{172.5 \times 10^3 \text{ kN/m}^2} = \mathbf{0.6 \times 10^{-3}\ m^3/m\ of\ the\ wall}$$ ■