

SEVENTH EDITION

PRINCIPLES OF

FOUNDATION ENGINEERING



BRAJA DAS

Chapter 10: Braced Cuts

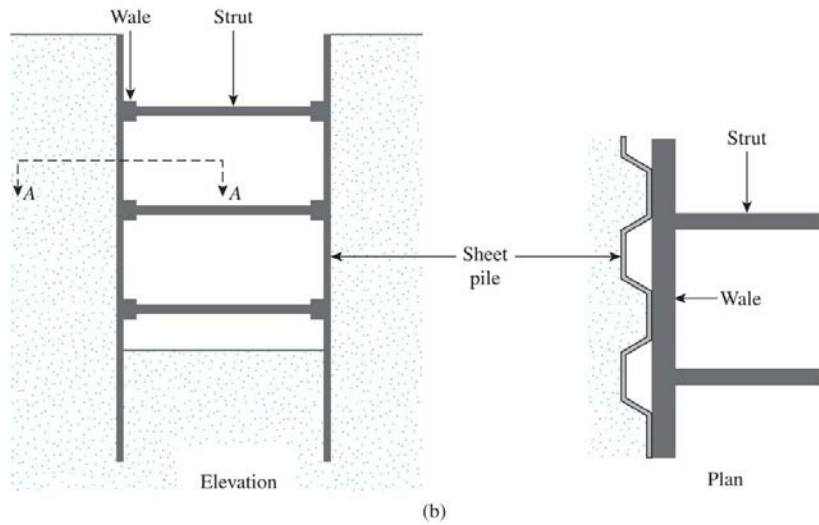
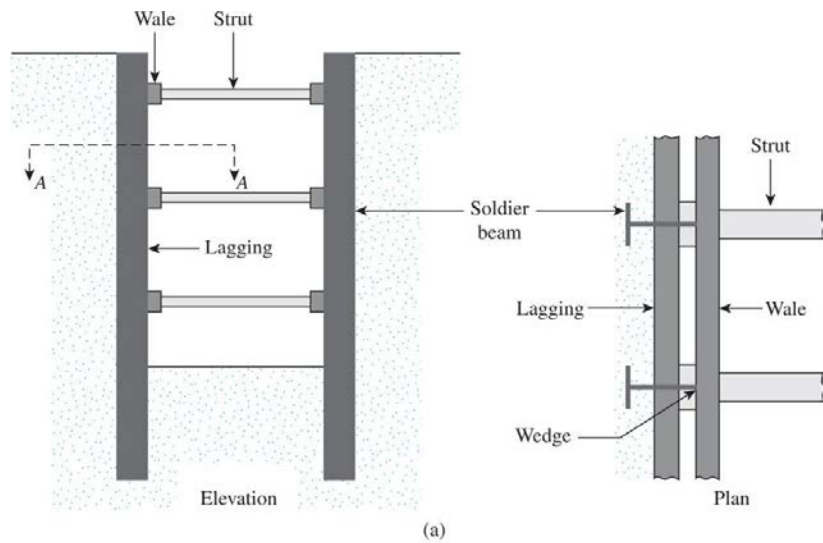


Figure 10.1 Types of braced cut: (a) use of soldier beams; (b) use of sheet piles

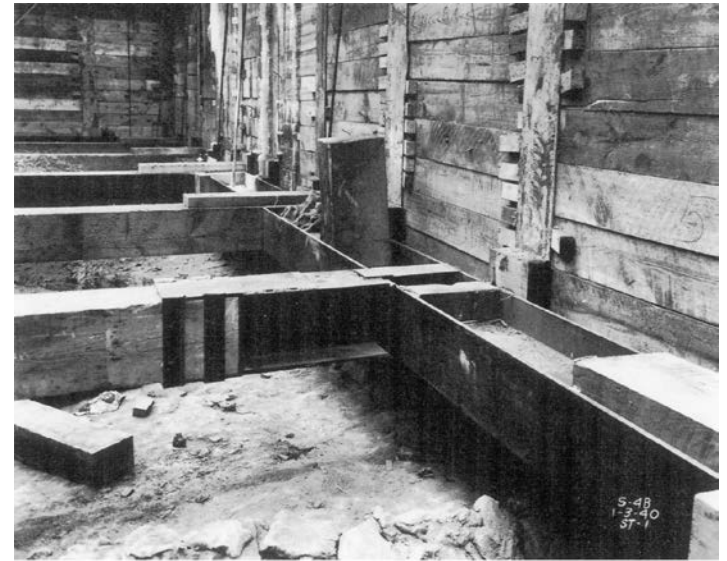


Figure 10.2 Braced cut in Chicago Subway construction, January 1940 (Courtesy of Ralph B.



Figure 10.3 Braced cut in the construction of Washington, DC Metro, May 1974 (Courtesy of Ralph B. Peck)

Pressure envelope for Braced-cut Design

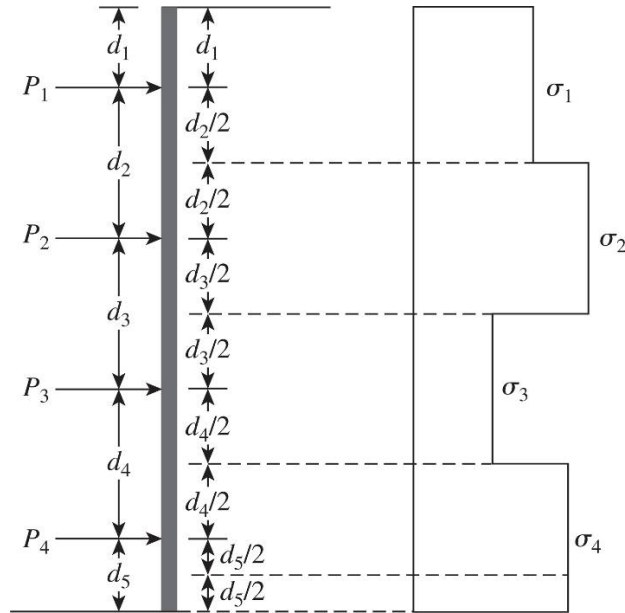


Figure 10.4 Procedure for calculating apparent-pressure diagram from measured strut loads

$$\sigma_1 = \frac{P_1}{(s) \left(d_1 + \frac{d_2}{2} \right)}$$

$$\sigma_2 = \frac{P_2}{(s) \left(\frac{d_2}{2} + \frac{d_3}{2} \right)}$$

$$\sigma_3 = \frac{P_3}{(s) \left(\frac{d_3}{2} + \frac{d_4}{2} \right)}$$

$$\sigma_4 = \frac{P_4}{(s) \left(\frac{d_4}{2} + \frac{d_5}{2} \right)}$$

Pressure envelope for Braced-cut Design (Peck 1969)

$$\sigma_a = 0.65\gamma H K_a$$

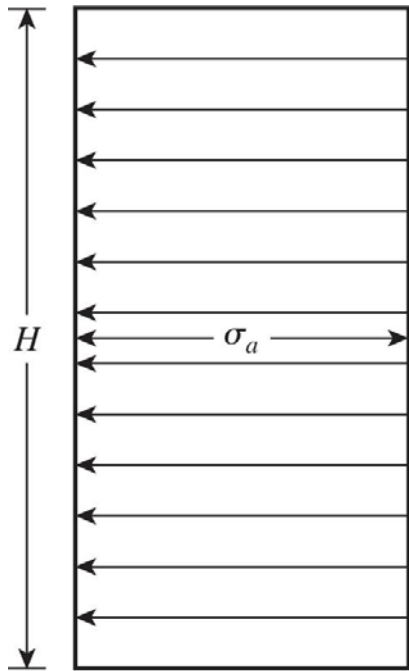


Figure 10.5 Peck's (1969) apparent-pressure envelope for cuts in sand

Larger of :

$$\sigma_a = \gamma H \left[1 - \left(\frac{4c}{\gamma H} \right) \right] \text{ and } \sigma_a = 0.3\gamma H$$

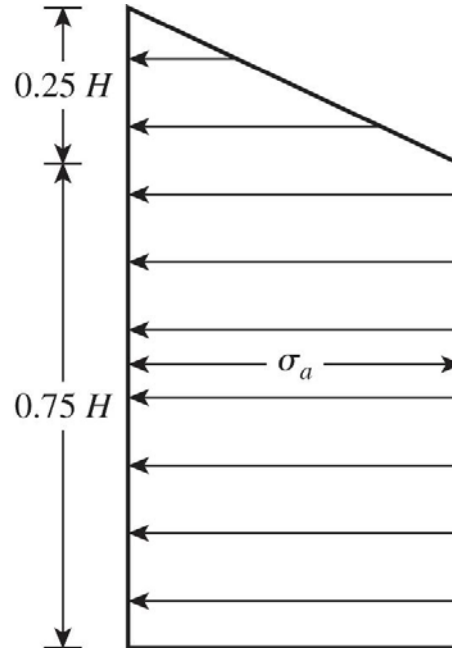


Figure 10.6 Peck's (1969) apparent-pressure envelope for cuts in soft to medium clay

$$\sigma_a = 0.2\gamma H \text{ to } 0.4\gamma H$$

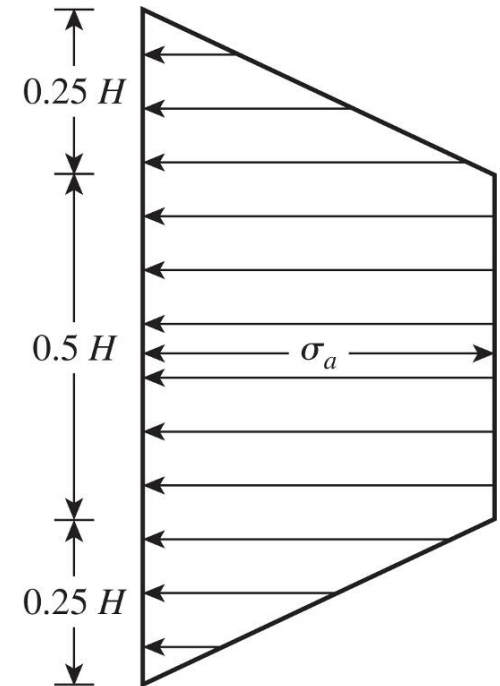


Figure 10.7 Peck's (1969) apparent-pressure envelope for cuts in stiff clay

Pressure envelope for cuts in layered soil

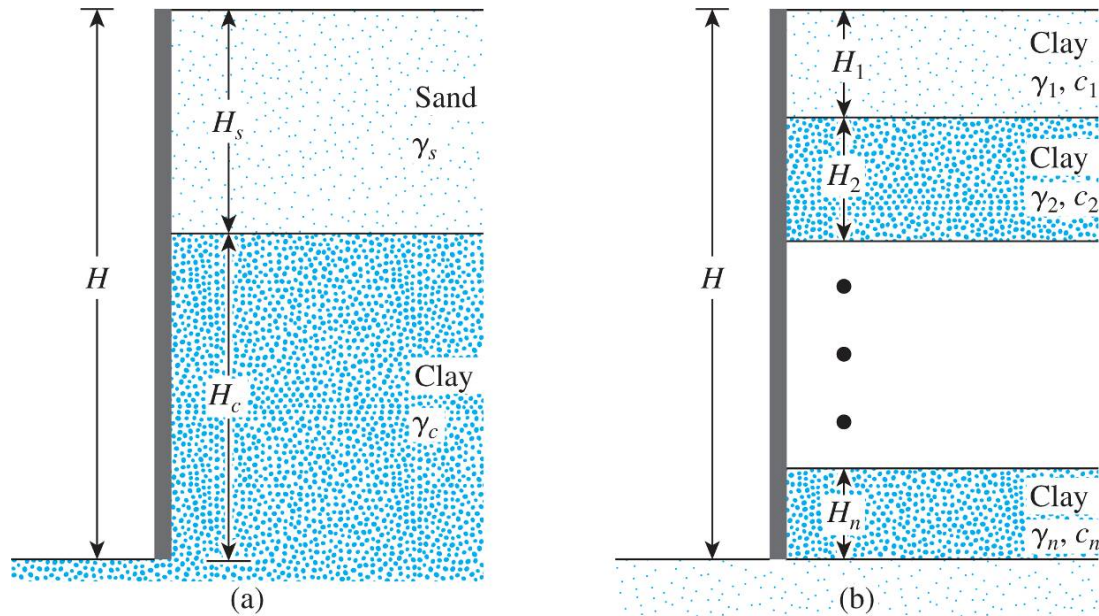


Figure 10.8 Layered soils in braced cuts

$$c_{av} = \frac{1}{2H} \left[\gamma_s K_s H_s^2 \tan \phi'_s + (H - H_s) n' q_u \right]$$

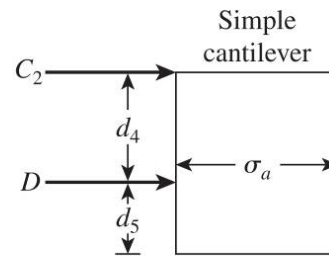
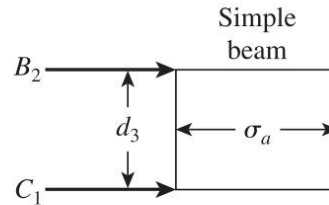
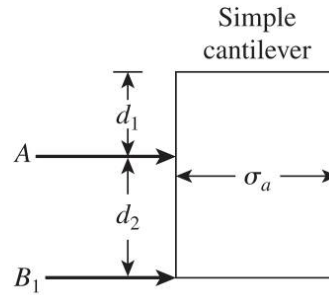
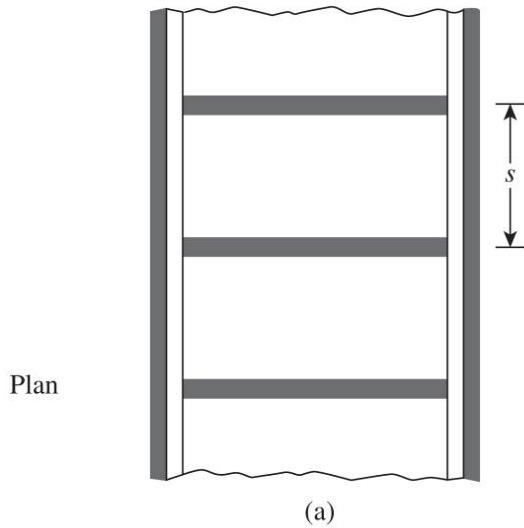
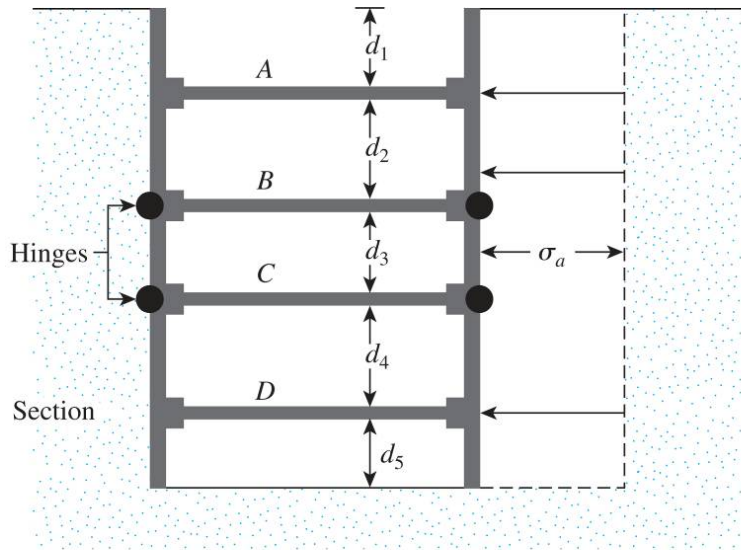
n' = coefficient of progressive failure (0.5 to 1.0), average 0.75

$$\gamma_a = \frac{1}{H} \left[\gamma_s H_s + (H - H_s) \gamma_c \right]$$

$$c_{av} = \frac{1}{H} \left[c_1 H_1 + c_2 H_2 + \dots + c_n H_n \right]$$

$$\gamma_a = \frac{1}{H} \left[\gamma_1 H_1 + \gamma_2 H_2 + \dots + \gamma_n H_n \right]$$

Design of various components of a braced cut



Struts

$$\sigma'_a = \gamma z_c K_a - 2c' \sqrt{K_a}$$

$$\sigma'_a = 0 = \gamma z_c K_a - 2c' \sqrt{K_a}$$

$$z_c = \frac{2c'}{\sqrt{K_a} \gamma}$$

Sheet Piles

$$S = \frac{M_{\max}}{\sigma_{all}}$$

Wales

$$\text{At level A, } M_{\max} = \frac{(A)(s^2)}{8}$$

$$\text{At level B, } M_{\max} = \frac{(B_1 + B_2)(s^2)}{8}$$

$$\text{At level C, } M_{\max} = \frac{(C_1 + C_2)(s^2)}{8}$$

$$\text{At level D, } M_{\max} = \frac{(D)(s^2)}{8}$$

Figure 10.9 Determination of strut loads: (a) section and plan of the cut; (b) method for determining strut loads

$$S = \frac{M_{\max}}{\sigma_{all}}$$

Bottom Heave of a cut in Clay

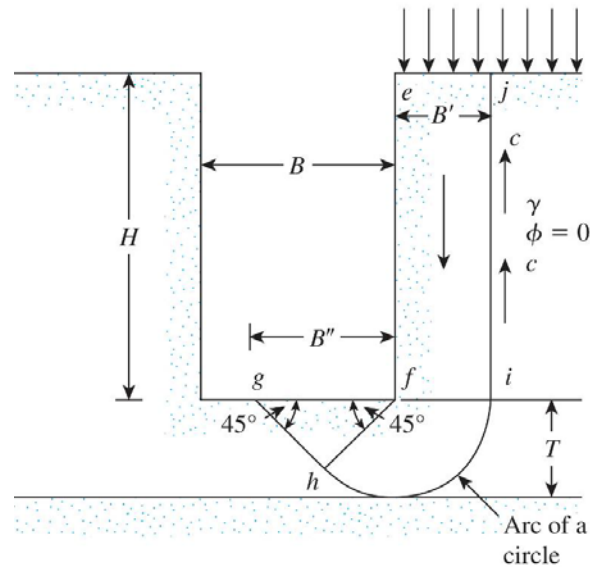


Figure 10.17 Heaving in braced cuts in clay

$$q_{ult} = cN_c$$

$$q = \gamma H + q - \frac{cH}{B'}$$

$$FS = \frac{q_{ult}}{q} = \frac{cN_c}{\gamma H + q - \frac{cH}{B'}}$$

$$FS = \frac{q_{ult}}{q} = \frac{cN_c \left(1 + 0.2 \frac{B'}{L} \right)}{\gamma H + q - \frac{cH}{B'}} \quad \text{where, } B' = T \text{ or } \frac{B}{\sqrt{2}}$$

$$FS = \frac{q_{ult}}{q} = \frac{5.14c \left(1 + 0.2 \frac{B''}{L} \right) + \frac{cH}{B'}}{\gamma H + q}$$

where, $B' = T$ if $T \leq \frac{B}{\sqrt{2}}$; $B' = \frac{B}{\sqrt{2}}$ if $T > \frac{B}{\sqrt{2}}$; $B'' = \sqrt{2}B'$

Bottom Heave of a cut in Clay

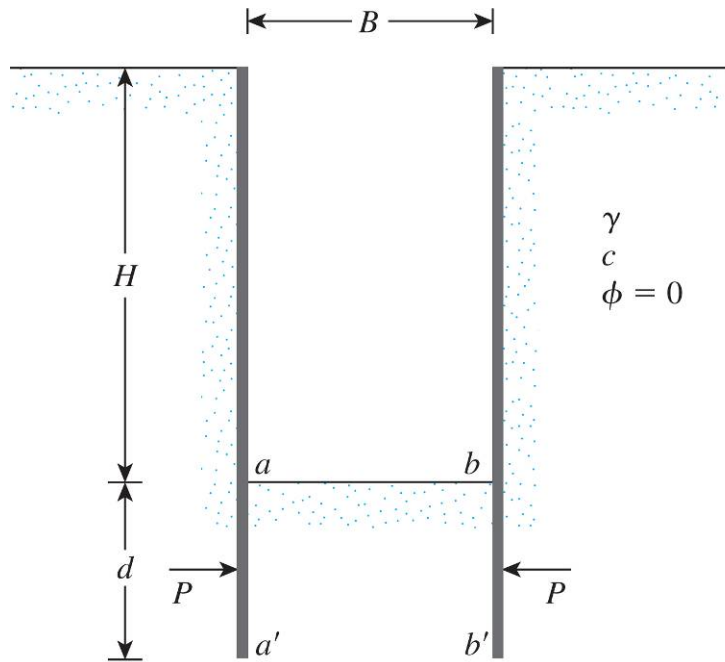
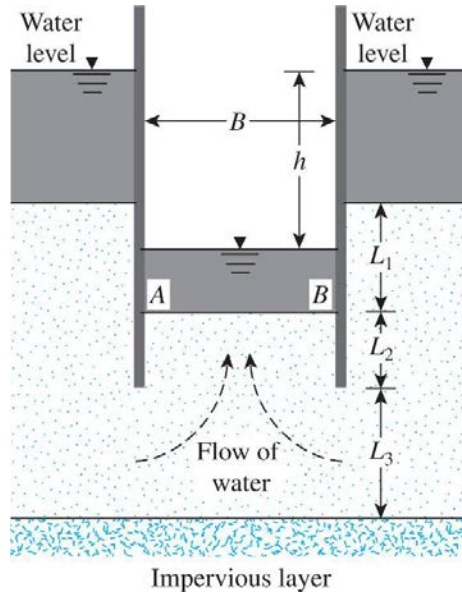


Figure 10.18 Force on the buried length of sheet pile

$$P = 0.7(\gamma HB - 1.4cH - \pi cB) \quad \text{for } d > 0.47B$$

$$P = 1.5d \left(\gamma H - \frac{1.4cH}{B} - \pi c \right) \quad \text{for } d < 0.47B$$

Bottom Heave of a cut in Sand

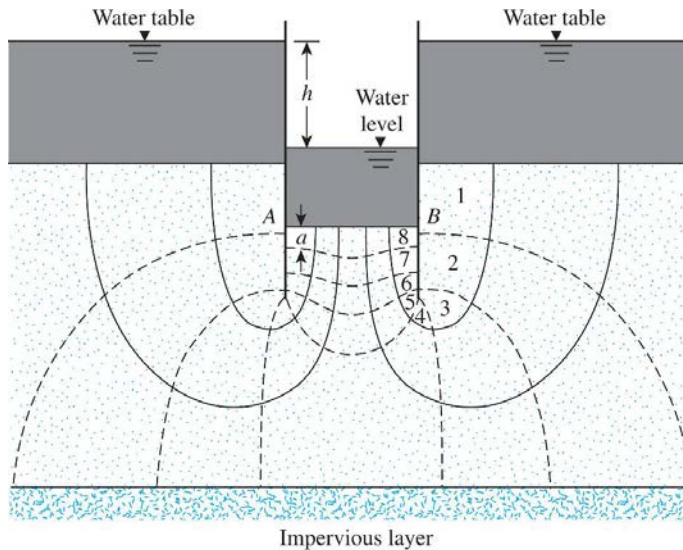


$$\text{Maximum exit gradient, } i_{\max(\text{exit})} = \frac{h}{a} = \frac{h}{N_d a}$$

where, a = length of the flow element at A or B

N_d = number of drops

Figure 10.20 Stability of the bottom of a cut in sand



$$\text{Factor of safety against piping, } FS = \frac{i_{cr}}{i_{\max(\text{exit})}}$$

$$i_{cr} = \text{critical hydraulic gradient} = \frac{G_s - 1}{e + 1}$$

Magnitude of i_{cr} varies between 0.9 and 1.1,
with average value of 1

Figure 10.21 Determining the factor of safety against piping by drawing a flow net

Bottom Heave of a cut in Sand

1. Determine the modulus, m , by obtaining $2L_2/B$ or $(B/2L_2)$ and $2L_1/B$

2. With the known modulus and $2L_1/B$, determine $L_2 i_{\text{exit(max)}}/h$ using Figure 10.23

3. Factor of safety against piping, $FS = \frac{i_{\text{cr}}}{i_{\text{max(exit)}}$
 $i_{\text{cr}} = \text{critical hydraulic gradient} = \frac{G_s - 1}{e + 1}$

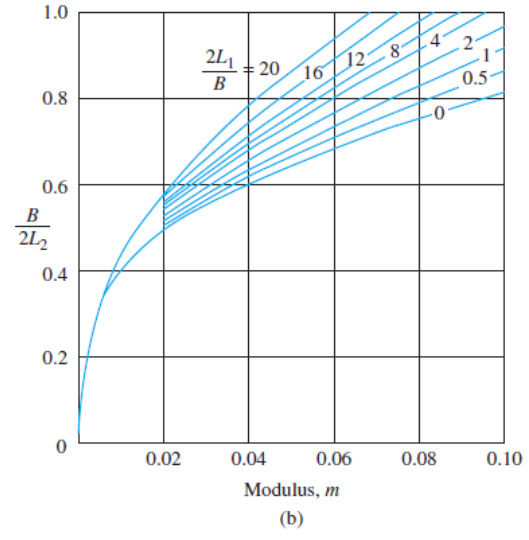
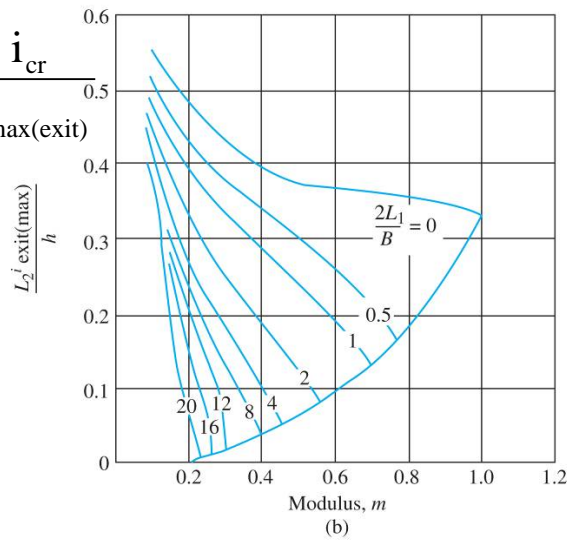
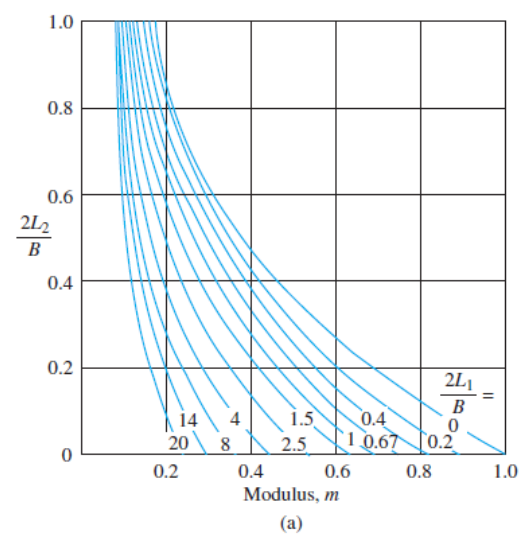
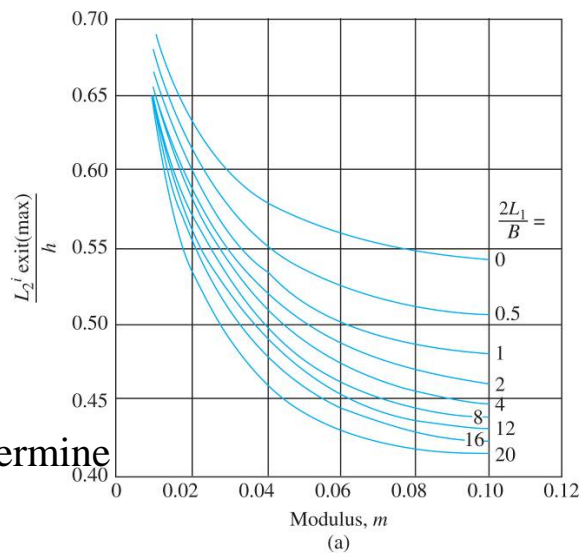


Figure 10.23 Variation of maximum exit gradient with modulus (From *Groundwater and Seepage*, by M. E. Harr. Copyright 1962 by McGraw-Hill. Used with permission.)

Figure 10.22 Variation of modulus (From *Groundwater and Seepage*, by M. E. Harr. Copyright 1962 by McGraw-Hill. Used with permission.)

Bottom Heave of a cut in Sand

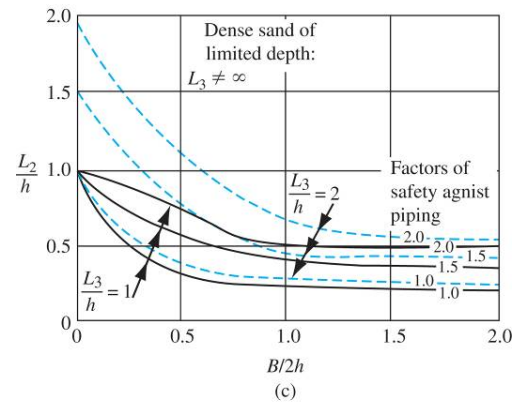
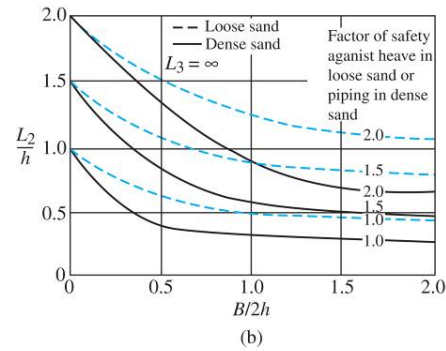
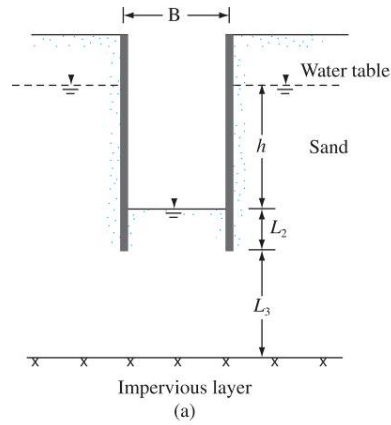


Figure 10.24 Influence of seepage on the stability of sheeted excavation (US Department of Navy, 1971.)

Lateral Yielding of Sheet piles and ground settlement

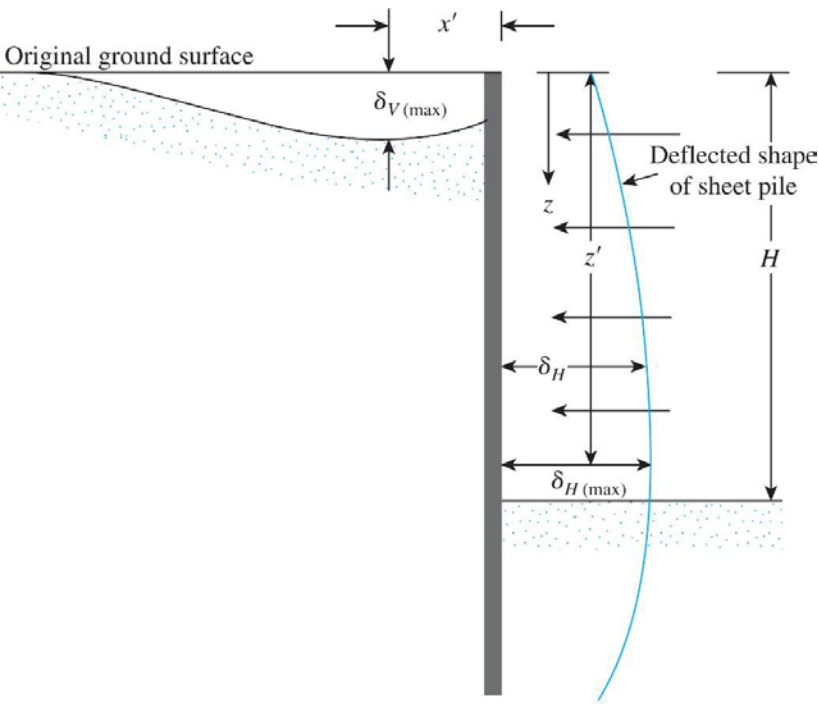


Figure 10.25 Lateral yielding of sheet pile and ground settlement

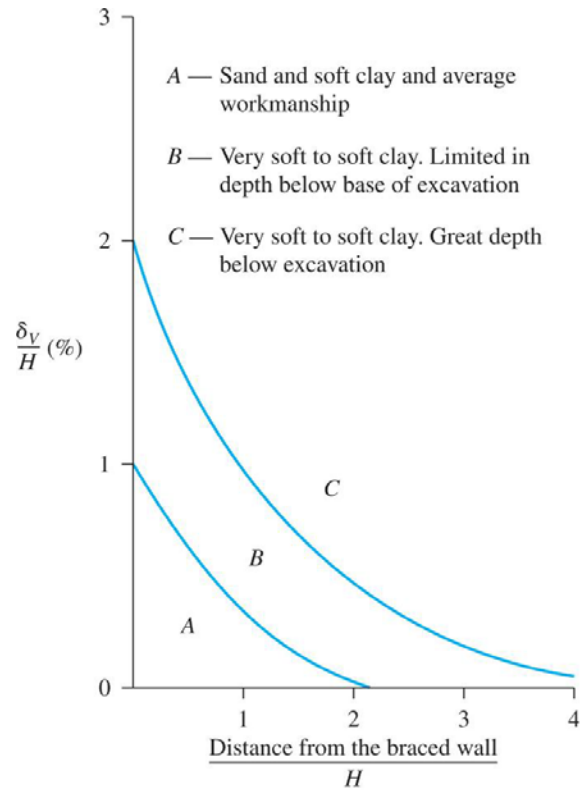


Figure 10.26 Variation of ground settlement with distance (From Peck, R. B. (1969). "Deep Excavation and Tunneling in Soft Ground," Proceedings Seventh International Conference on Soil Mechanics and Foundation Engineering, Mexico City, State-of-the-Art Volume, pp. 225–290. With permission from ASCE.)

Draw the earth pressure envelope and determine the strut load at levels A, B, and C

Given : $\gamma = 16 \text{ kN/m}^3$; $\phi' = 38^\circ$; and $c' = 0$

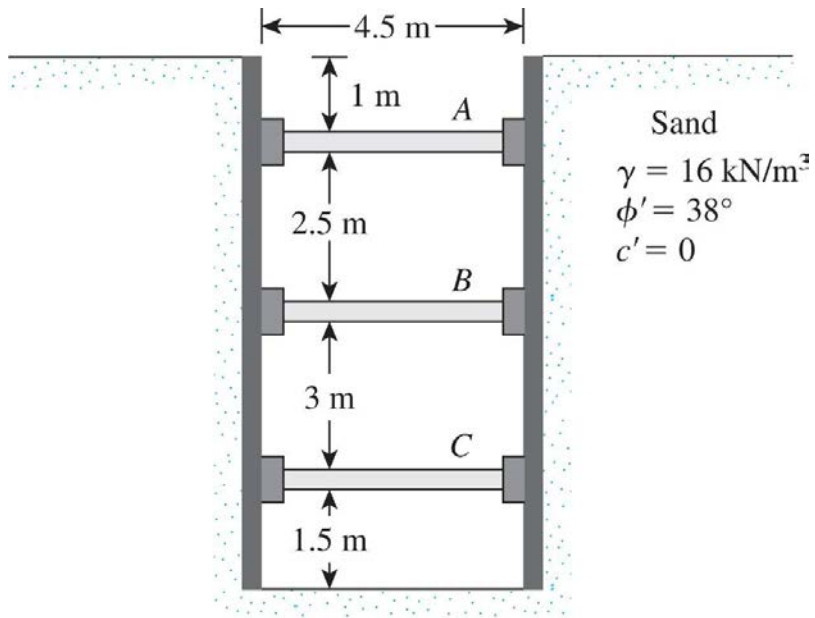


Figure P10.1

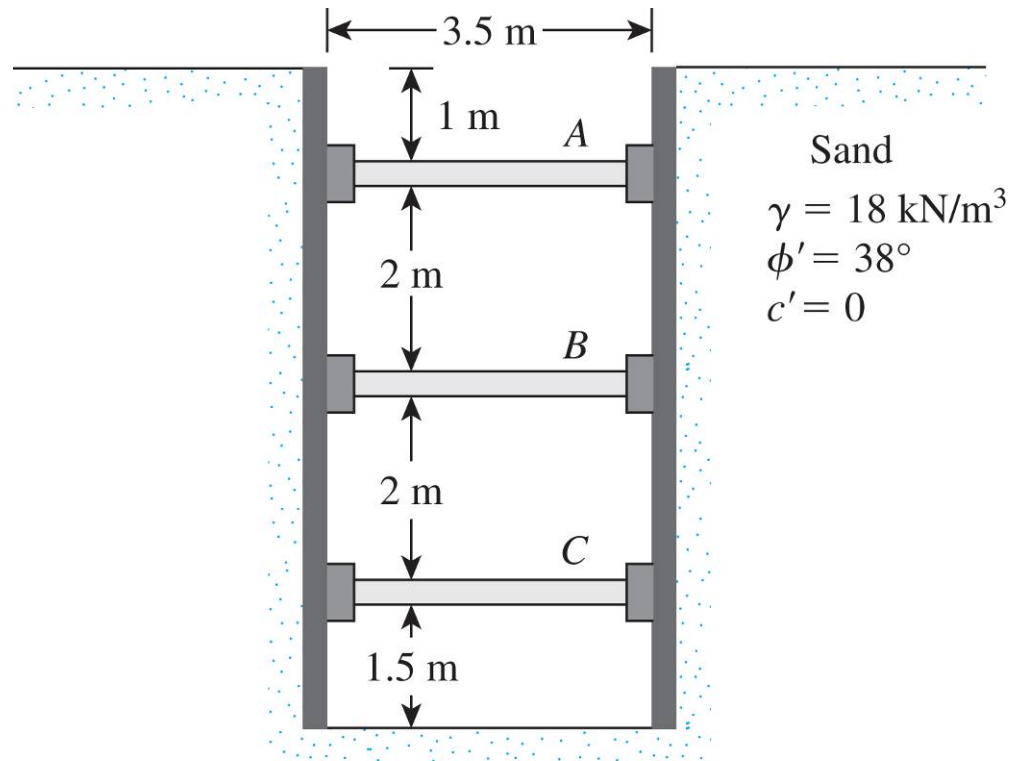


Figure P10.3

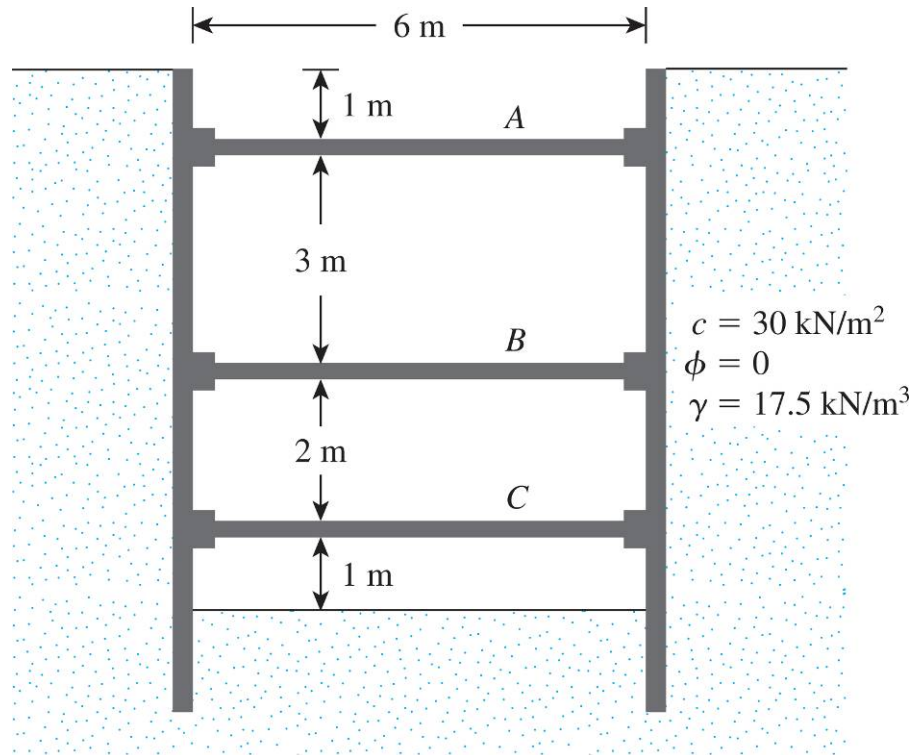


Figure P10.7