DESIGN OF SHEET PILE WALLS

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Sheet pile walls are thin structural elements driven next to each other. They may be made up of

- ✓ Wood (timber)
- ✓ Reinforced concrete
- ✓ Precast concrete sheet piles
- ✓ Steel
- ✓ Aluminum sheet piles are also marketed.

Connected or semi-connected sheet piles are often used to build continuous walls for waterfront structures that range from small waterfront pleasure boat launching facilities to large dock facilities (Das, 2011) .

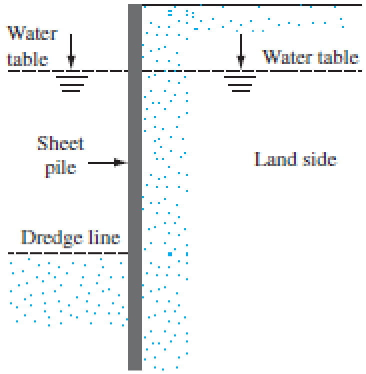
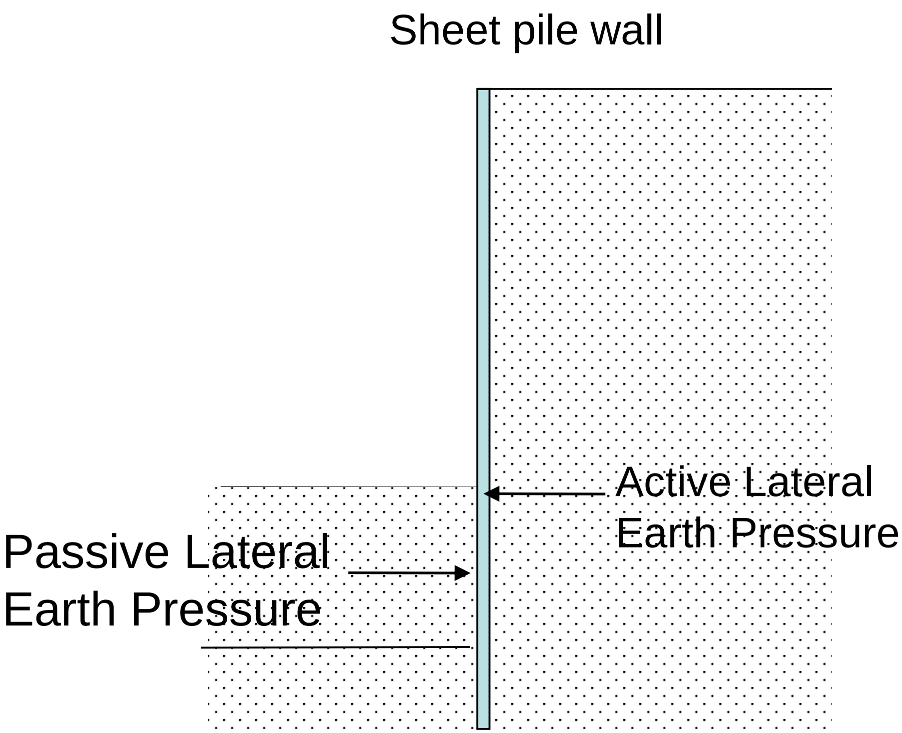


Figure 9.1 Example of waterfront sheet-pile wall

Sheet pile walls



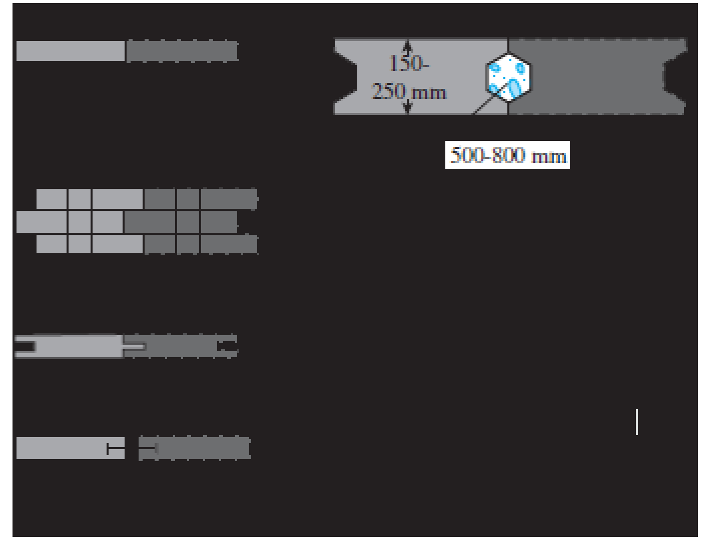
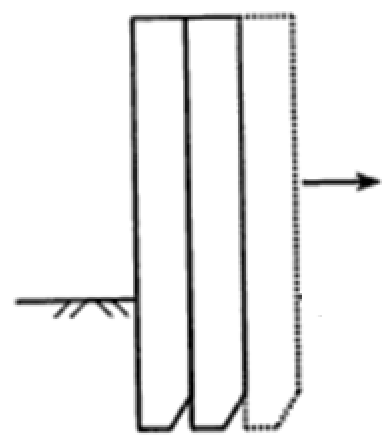


Figure 9.2 Various types of wooden and concrete sheet pile

<u>Construction Method: They are </u>driven next to each other.



Steel Sheet Piles

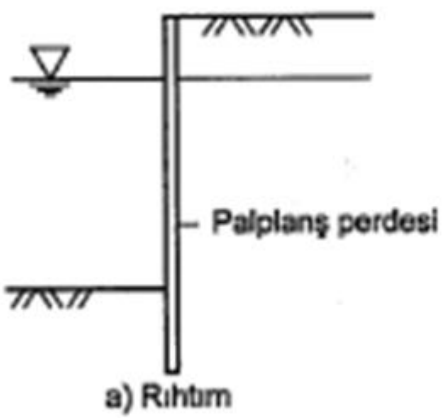

ShunLi Steel
ShunLi Steel
Sheet Pile Manufacturer【ShunLi Steel Group】www.sheetpiling-china.com

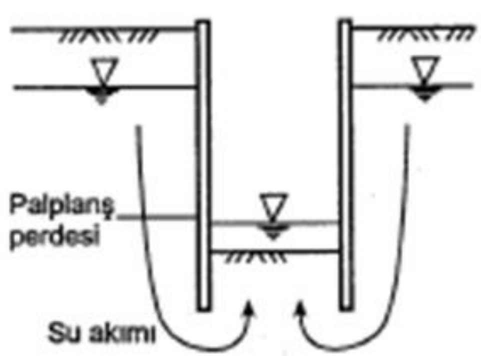

08/04/2004

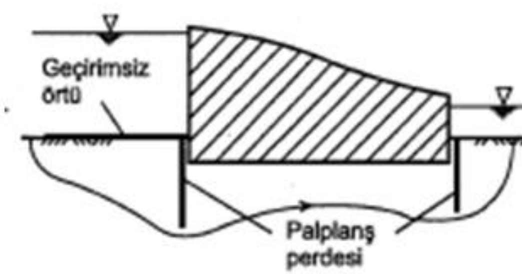
Use of Sheet Pile Walls

A. Permanent Structures (Water-front structures, Retaining structures, Slope Stabilization, Against scouring)
B. Temporary Structures (For excavation support)

Slope Stabilization







Water-front structures

9.2 Construction Methods

Sheet pile walls may be divided into two basic categories: (a) cantilever and (b) anchored.

In the construction of sheet pile walls, the sheet pile may be driven into the ground and then the backfill placed on the land side, or the sheet pile may first be driven into the ground and the soil in front of the sheet pile dredged. In either case, the soil used for backfill behind the sheet pile wall is usually granular. The soil below the dredge line may be sandy or clayey. The surface of soil on the water side is referred to as the *mud line* or *dredge line*.

Thus, construction methods generally can be divided into two categories (Tsinker, 1983):

1. Backfilled structure
2. Dredged structure

The sequence of construction for a *backfilled structure* is as follows (see Figure 9.5):

Step 1. Dredge the *in situ* soil in front and back of the proposed structure.
Step 2. Drive the sheet piles.
Step 3. Backfill up to the level of the anchor, and place the anchor system.
Step 4. Backfill up to the top of the wall.

For a cantilever type of wall, only Steps 1, 2, and 4 apply. The sequence of construction for a *dredged structure* is as follows (see Figure 9.6):

Step 1. Drive the sheet piles.
Step 2. Backfill up to the anchor level, and place the anchor system.
Step 3. Backfill up to the top of the wall.
Step 4. Dredge the front side of the wall.

With cantilever sheet pile walls, Step 2 is not required.

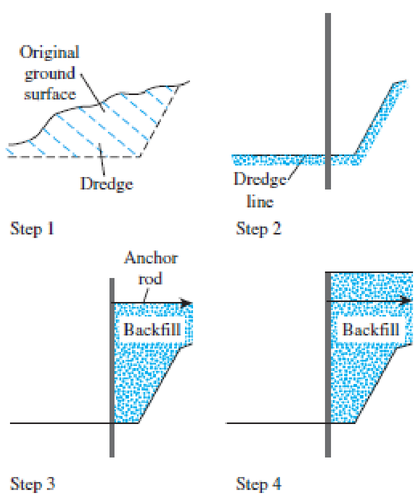


Figure 9.5 Sequence of construction for a backfilled structure

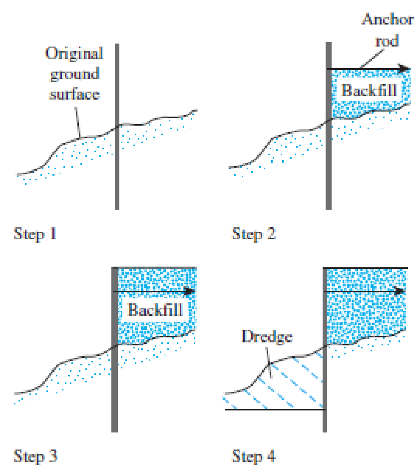
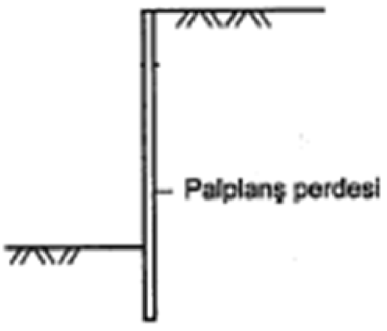


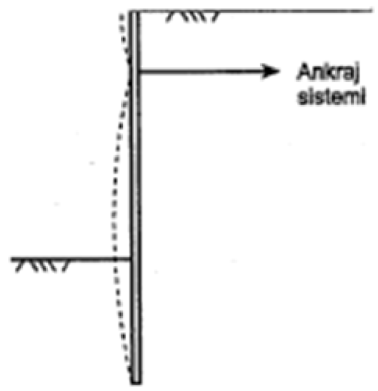
Figure 9.6 Sequence of construction for a dredged structure

Types of Sheet Pile Walls

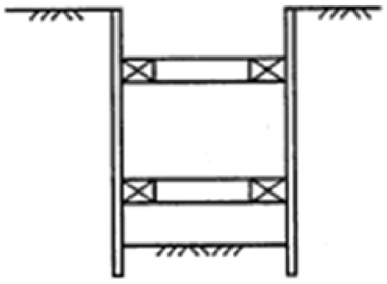
Types of sheet pile walls



Cantilever Sheet Pile Wall



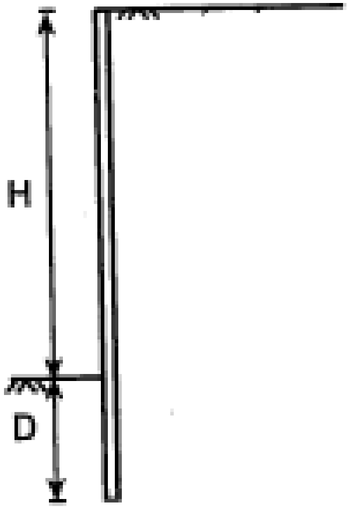
Anchored Sheet Pile Wall



Braced Excavation

Cantilever sheet pile walls

Sheet piles walls are classified with respect to their purpose of use in practice:
D=sheet pile penetration depth
H=Height of sheet pile



Cantilever sheet pile walls:

- Cantilever sheet pile walls are usually recommended for walls of moderate height about 6 m or less, measured above the dredge line.
- In such walls, the sheet piles act as a wide cantilever beam above the dredge line.

The basic principles for estimating net lateral pressure distribution on a cantilever sheet-pile wall can be explained with the aid of Figure 9.7.

The figure shows the nature of lateral yielding of a cantilever wall penetrating a sand layer below the dredge line.

- The wall rotates about point *O* (Figure 9.7a). Because the hydrostatic pressures at any depth from both sides of the wall will cancel each other, we consider only the effective lateral soil pressures.
- In zone *A,* the lateral pressure is just the active pressure from the land side. In zone *B,* because of the nature of yielding of the wall, there will be active pressure from the land side and passive pressure from the water side.
- The condition is reversed in zone *C*—that is, below the point of rotation, *O.*
- The net actual pressure distribution on the wall is like that shown in Figure 9.7b.

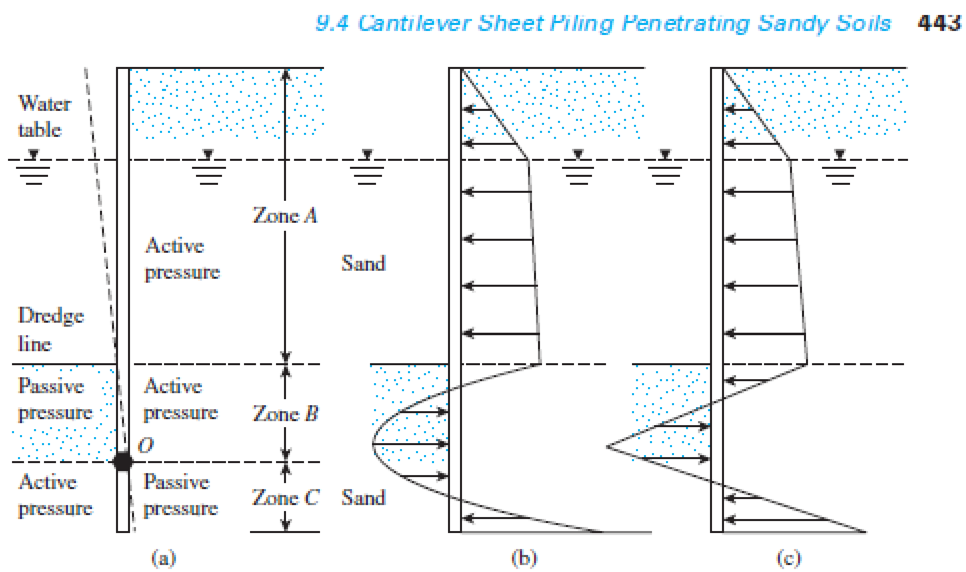


Figure 9.7 Cantilever sheet pile penetrating sand

Design steps in sheet pile walls

1. Determination of lateral earth pressures acting on the wall
2. Stability checks considering equilibrium of total lateral forces and moment of the forces
3. Determination of depth of penetration
4. Calculation of maximum bending moment value
5. The necessary profile of the sheet piling is then sized according to the allowable flexural stress of the sheet pile material,

$$S = \frac{M_{max}}{\sigma_{all}} \tag{9.23}$$

where

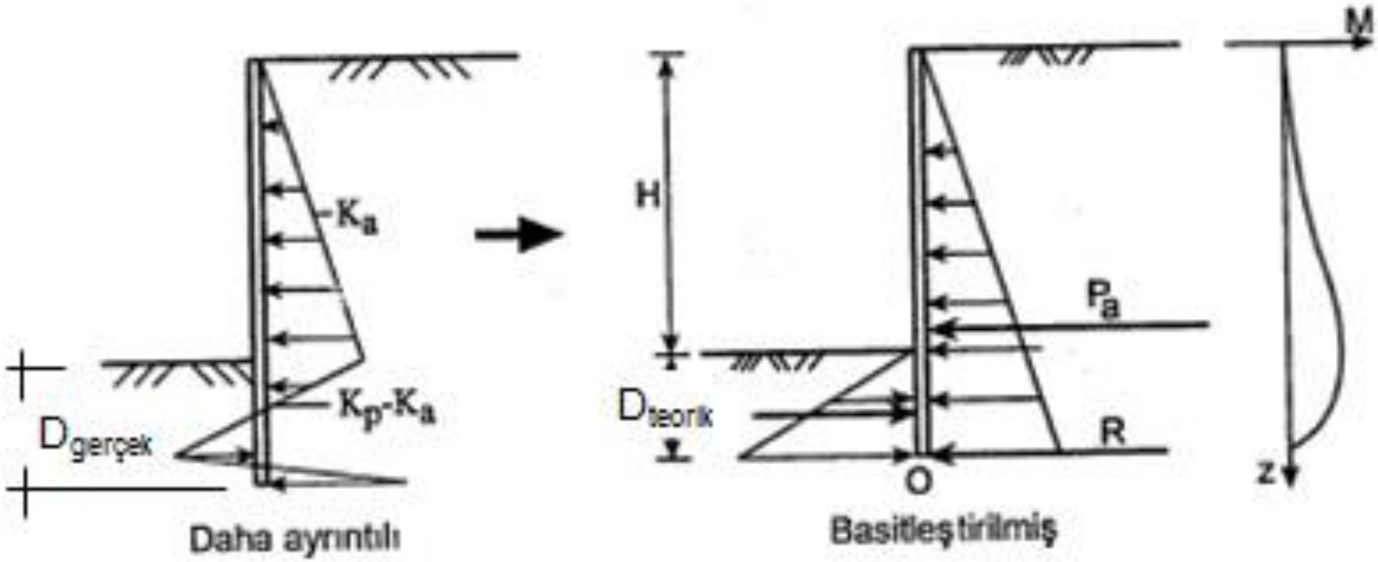
S = section modulus of the sheet pile required per unit length of the structure
σ_{all} = allowable flexural stress of the sheet pile

Type of steel	Allowable stress
ASTM A-328	170 MN/m^2
ASTM A-572	210 MN/m^2
ASTM A-690	210 MN/m^2

The depth of penetration for cantilever type retaining walls can be selected with respect to SPT-N value and Relative density as given in the below table.

SPT- N	Relative density	Penetration Depth
0-4	Very Loose	2.0H
5-10	Loose	1.5H
11-30	Medium Dense	1.25H
31-50	Dense	1.0H
>50	Very Dense	0.75H

Simplified solution for Cantilever type Sheet pile walls penetrating Sandy Soils



The portion below the rotation point is neglected and represented by a resultant force R;

For the stability of the wall, the principles of statics can now be applied

$\sum F_H=0$

$$\frac{1}{2}\gamma D_0^{\;2}K_p - R - \frac{1}{2}\gamma K_a (D_0 + H)^2 = 0$$

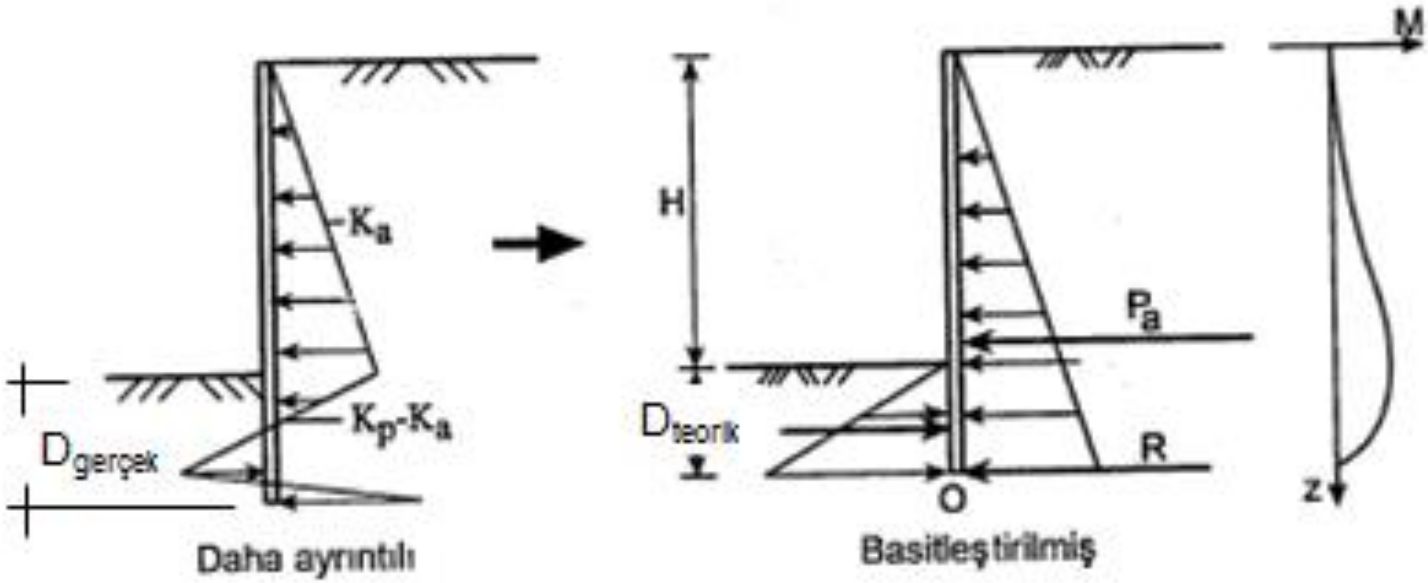
$D_0 = D_{theoretical}$

The value of R can be found with $\sum F_H=0$

Sum of moment of the forces per unit length of wall about point O

$\sum M_O=0$

$$\frac{1}{2}\gamma\left(\frac{D_0}{3}\right)^3 K_p - \frac{1}{2}\gamma K_a (D_0 + H)^3 (\frac{1}{3}) = 0$$



<u>In simplified solutions:</u>

The actual depth of penetration is increased by about 20 to 30%.

$$D_{actual} = 1.20 - 1.40(D_{theoretical})$$

Cantilever type Sheet pile walls penetrating Clayey Soils

At times, cantilever sheet piles must be driven into a clay layer possessing an undrained cohesion The net pressure diagram will be as shown in Figure 9.12.

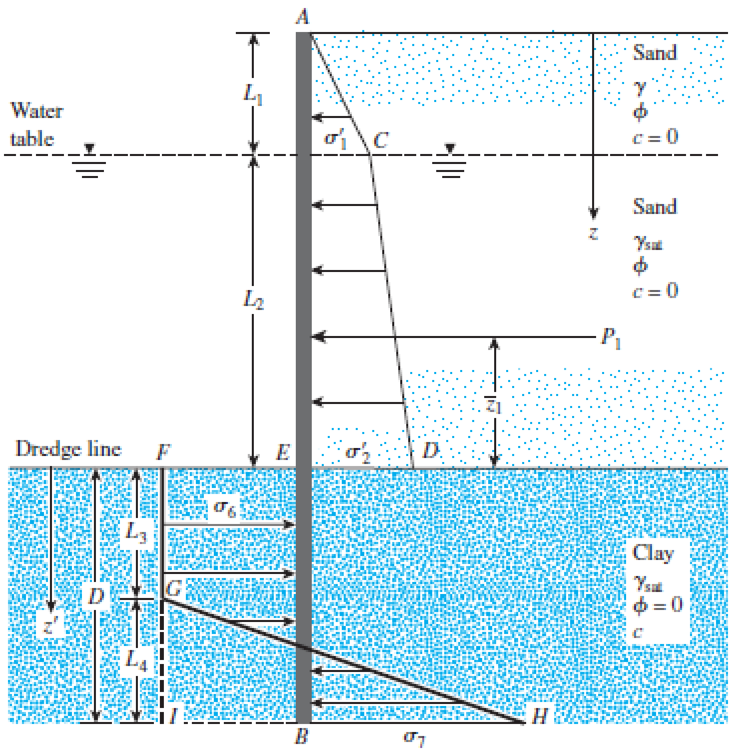
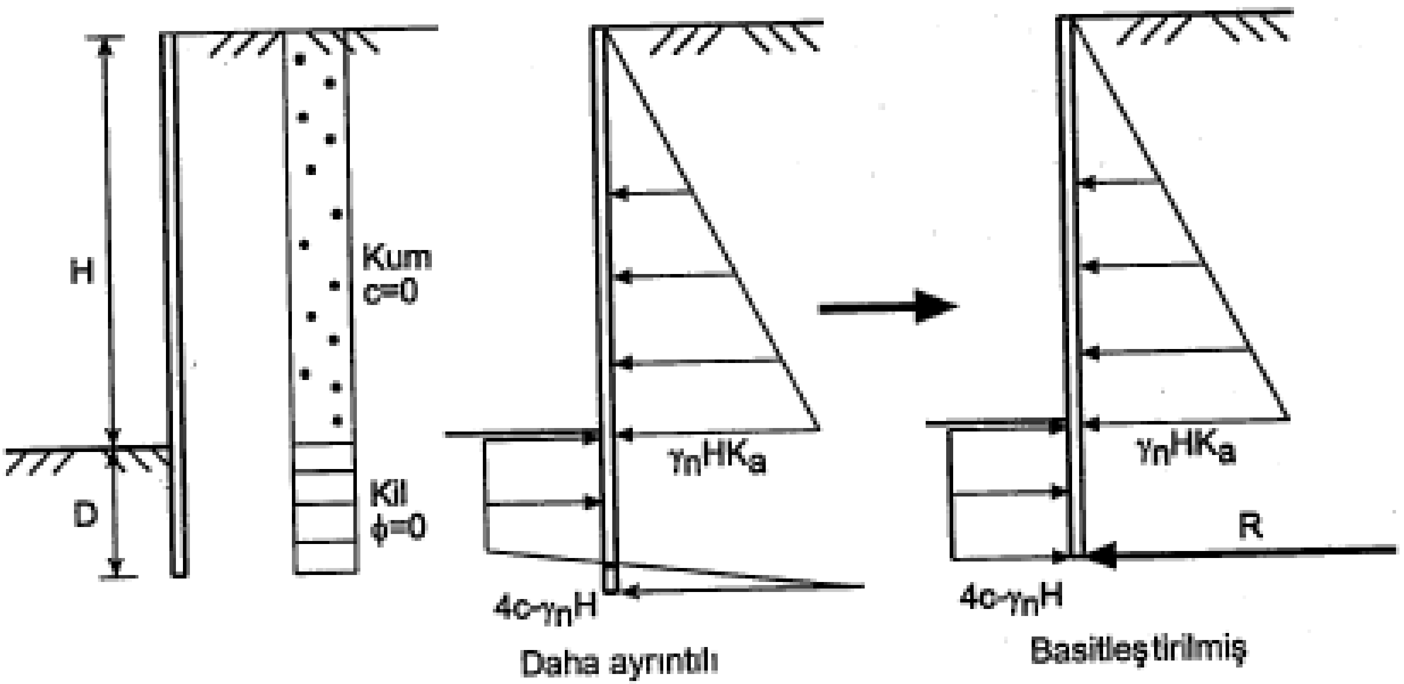


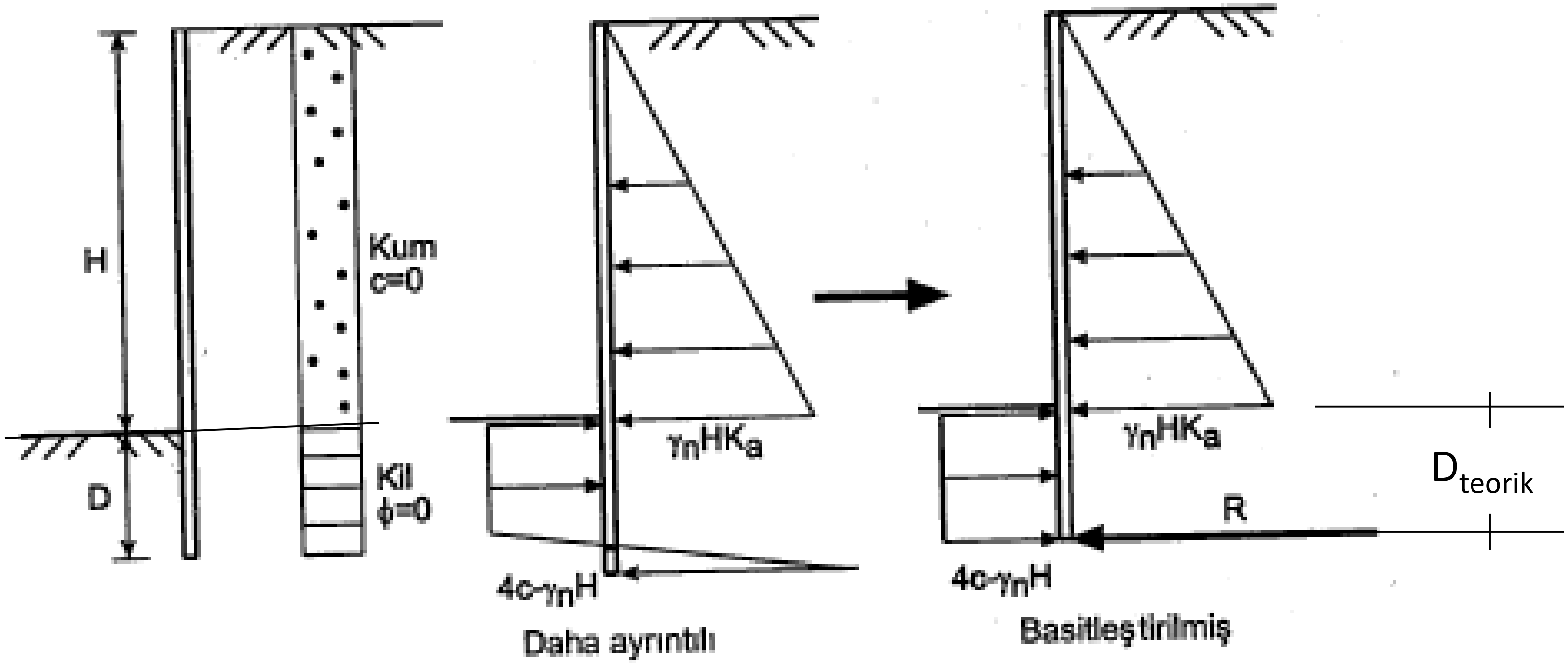
Figure 9.12 Cantilever sheet pile penetrating clay

Cantilever type Sheet pile walls penetrating Clayey Soils

For design purposes, the simplified version shown in the below figure may be used.



Simplified solution for sheet piles penetrating clay



The portion below the rotation point is neglected and represented by a resultant force R;
For the stability of the wall, the principles of statics can now be applied
$\sum F_H=0$
Sum of moment of the forces per unit length of wall about point O
$\sum M_O=0$

$$D_{actual} = 1.40 - 1.60(D_{theoretical})$$

9.8 Anchored Sheet-Pile Walls

When the height of the backfill material behind a cantilever sheet-pile wall exceeds about 6 m, tying the wall near the top to anchor plates, anchor walls, or anchor piles becomes more economical. This type of construction is referred to as *anchored sheet-pile wall* or an *anchored bulkhead.* Anchors minimize the depth of penetration required by the sheet piles and also reduce the cross-sectional area and weight of the sheet piles needed for construction. However, the tie rods and anchors must be carefully designed.

The two basic methods of designing anchored sheet-pile walls are (a) the *free earth support* method and (b) the *fixed earth support* method. Figure 9.16 shows the assumed nature of deflection of the sheet piles for the two methods.

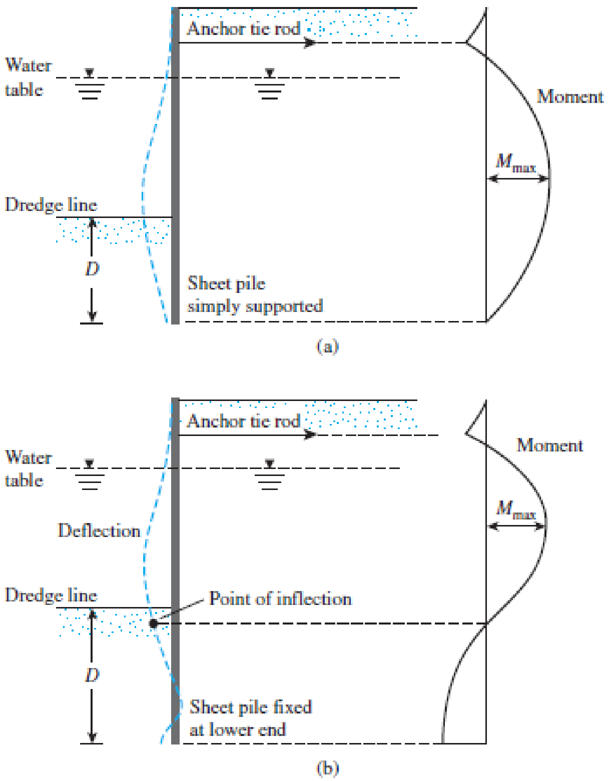


Figure 9.16 Nature of variation of deflection and moment for anchored sheet piles: (a) free earth support method; (b) fixed earth support method

Free Earth Support Method for Penetration of Sandy Soil

Figure 9.17 shows an anchor sheet-pile wall with a granular soil backfill; the wall has been driven into a granular soil. The tie rod connecting the sheet pile and the anchor is located at a depth l_1 below the top of the sheet-pile wall.

The diagram of the net pressure distribution above the dredge line is similar to that shown in Figure 9.8. At depth $z = L_1, \sigma'_1 = \gamma L_1 K_a$, and at $z = L_1 + L_2, \sigma'_2 = (\gamma L_1 + \gamma' L_2)K_a$. Below the dredge line, the net pressure will be zero at $z = L_1 + L_2 + L_3$. The relation for L_3 is given by Eq. (9.6), or

$$L_3 = \frac{\sigma'_2}{\gamma'(K_p - K_a)}$$

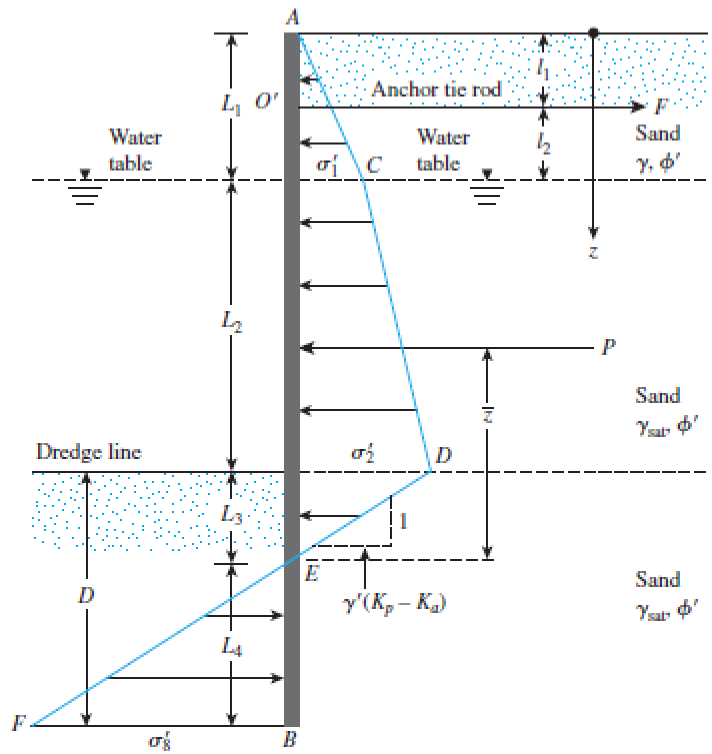


Figure 9.17 Anchored sheet-pile wall penetrating sand

At $z = L_1 + L_2 + L_3 + L_4$, the net pressure is given by

$$\sigma'_8 = \gamma'(K_p - K_a)L_4 \tag{9.65}$$

Note that the slope of the line *DEF* is 1 vertical to $\gamma'(K_p - K_a)$ horizontal.

For equilibrium of the sheet pile, Σ horizontal forces $= 0$, and Σ moment about $O' = 0$. (*Note:* Point O' is located at the level of the tie rod.)

Summing the forces in the horizontal direction (per unit length of the wall) gives

$$\text{Area of the pressure diagram } ACDE - \text{area of } EBF - F = 0$$

where F = tension in the tie rod/unit length of the wall, or

$$P - \tfrac{1}{2}\sigma'_8 L_4 - F = 0$$

or

$$\boxed{F = P - \tfrac{1}{2}[\gamma'(K_p - K_a)]L_4^2} \tag{9.66}$$

where P = area of the pressure diagram *ACDE*. Now, taking the moment about point O' gives

$$-P[(L_1 + L_2 + L_3) - (\bar{z} + l_1)] + \tfrac{1}{2}[\gamma'(K_p - K_a)]L_4^2(l_2 + L_2 + L_3 + \tfrac{2}{3}L_4) = 0$$

or

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

Equation (9.67) may be solved by trial and error to determine the theoretical depth, L_4:

$$D_{\text{theoretical}} = L_3 + L_4$$

The theoretical depth is increased by about 30 to 40% for actual construction, or

$$D_{\text{actual}} = 1.3 \text{ to } 1.4 D_{\text{theoretical}} \tag{9.68}$$

The step-by-step procedure in Section 9.4 indicated that a factor of safety can be applied to K_p at the beginning [i.e., $K_{p(\text{design})} = K_p/\text{FS}$]. If that is done, there is no need to increase the theoretical depth by 30 to 40%. This approach is often more conservative.

Fixed Earth-Support Method for Penetration into Sandy Soil

When using the fixed earth support method, we assume that the toe of the pile is restrained from rotating, as shown in Figure 9.28a. In the fixed earth support solution, a simplified method called the *equivalent beam solution* is generally used to calculate L_3 and, thus, D. The development of the equivalent beam method is generally attributed to Blum (1931).

In order to understand this method, compare the sheet pile to a loaded cantilever beam *RSTU*, as shown in Figure 9.29. Note that the support at T for the beam is equivalent to the *anchor load reaction* (F) on the sheet pile (Figure 9.28). It can be seen that the point S of the beam *RSTU* is the inflection point of the elastic line of the beam, which is equivalent to point I in Figure 9.28. It the beam is cut at S and a free support (reaction P_s) is provided at that point, the bending moment diagram for portion *STU* of the beam will remain unchanged. This beam *STU* will be equivalent to the section *STU* of the beam *RSTU*. The force P' shown in Figure 9.28a at I will be equivalent to the reaction P_s on the beam (Figure 9.29).

The following is an approximate procedure for the design of an anchored sheet-pile wall (Cornfield, 1975). Refer to Figure 9.28.

Step 1. Determine L_5, which is a function of the soil friction angle ϕ' below the dredge line, from the following:

ϕ' (deg)	$\dfrac{L_5}{L_1 + L_2}$
30	0.08
35	0.03
40	0

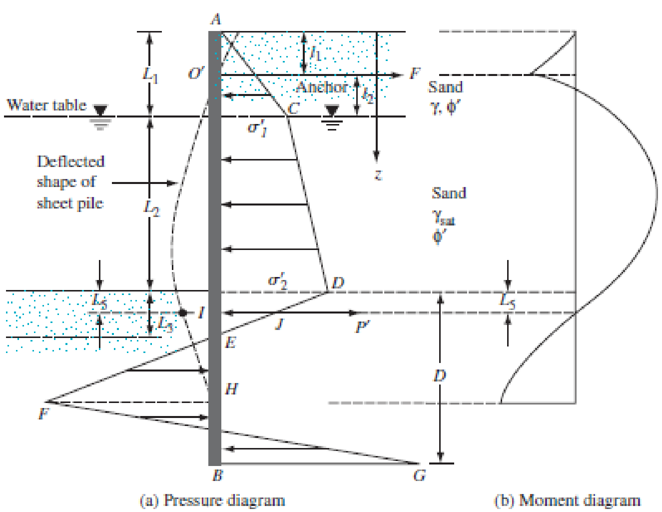


FIGURE 9.28 Fixed earth support method for penetration of sandy soil

Fixed Earth-Support Method for Penetration into Sandy Soil

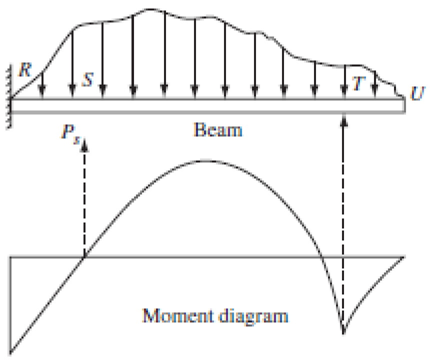


Figure 9.29 Equivalent cantilever beam concept

Step 2. Calculate the span of the equivalent beam as $l_2 + L_2 + L_5 = L'$.

Step 3. Calculate the total load of the span, W. This is the area of the pressure diagram between O' and I.

Step 4. Calculate the maximum moment, M_{max}, as $WL'/8$.

Step 5. Calculate P' by taking the moment about O', or

$$P' = \frac{1}{L'}(\text{moment of area } ACDJI \text{ about } O') \tag{9.82}$$

Step 6. Calculate D as

$$D = L_5 + 1.2\sqrt{\frac{6P'}{(K_p - K_a)\gamma'}} \tag{9.83}$$

Step 7. Calculate the anchor force per unit length, F, by taking the moment about I, or

$$F = \frac{1}{L'}(\text{moment of area } ACDJI \text{ about } I)$$

Example

Example 9.9

Consider the anchored sheet-pile structure described in Example 9.5. Using the equivalent beam method described in Section 9.13, determine

- **a.** Maximum moment
- **b.** Theoretical depth of penetration
- **c.** Anchor force per unit length of the structure

Solution

Part a

Determination of L_5: For $\phi' = 30°$,

$$\frac{L_5}{L_1 + L_2} = 0.08$$

$$\frac{L_5}{3.05 + 6.1} = 0.08$$

$$L_5 = 0.73$$

Net Pressure Diagram: From Example 9.5, $K_a = \frac{1}{3}$, $K_p = 3$, $\gamma = 16\ \text{kN/m}^3$, $\gamma' = 9.69\ \text{kN/m}^3$, $\sigma_1' = 16.27\ \text{kN/m}^2$, $\sigma_2' = 35.97\ \text{kN/m}^2$. The net active pressure at a depth L_5 below the dredge line can be calculated as

$$\sigma_2' - \gamma'(K_p - K_a)L_5 = 35.97 - (9.69)(3 - 0.333)(0.73) = 17.1\ \text{kN/m}^2$$

The net pressure diagram from $z = 0$ to $z = L_1 + L_2 + L_5$ is shown in Figure 9.30.

Maximum Moment:

$$W = \left(\frac{1}{2}\right)(8.16 + 16.27)(1.52) + \left(\frac{1}{2}\right)(6.1)(16.27 + 35.97) + \left(\frac{1}{2}\right)(0.73)(35.97 + 17.1)$$

$$= 197.2\ \text{kN/m}$$

$$L' = l_2 + L_2 + L_5 = 1.52 + 6.1 + 0.73 = 8.35\ \text{m}$$

$$M_{\max} = \frac{WL'}{8} = \frac{(197.2)(8.35)}{8} = \mathbf{205.8\ kN \cdot m/m}$$

Part b

$$P' = \frac{1}{L'}(\text{moment of area } ACDJI \text{ about } O')$$

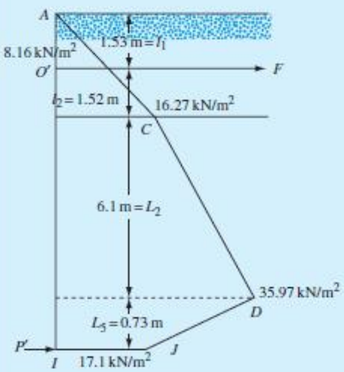


FIGURE 9.30

$$P' = \frac{1}{8.35}\left[\begin{array}{l}\left(\frac{1}{2}\right)(16.27)(3.05)\left(\frac{2}{3}\times 3.05 - 1.53\right) + (16.27)(6.1)\left(1.52 + \frac{6.1}{2}\right) \\ + \left(\frac{1}{2}\right)(6.1)(35.97 - 16.27)\left(1.52 + \frac{2}{3}\times 6.1\right) + \left(\frac{1}{2}\right)(35.97 + 17.1) \\ \times (0.73)\left(1.52 + 6.1 + \underset{\substack{\uparrow \\ \text{Approximate}}}{\frac{0.73}{2}}\right)\end{array}\right]$$

$$= 114.48 \text{ kN/m}$$

From Eq. (9.83)

$$D = L_5 + 1.2\sqrt{\frac{6P'}{(K_p - K_a)\gamma'}} = 0.73 + 1.2\sqrt{\frac{(6)(114.48)}{(3 - 0.333)(9.69)}} = \mathbf{6.92\ m}$$

Part c

Taking the moment about I (Figure 9.30)

$$F = \frac{1}{8.35}\left[\begin{array}{l}\left(\frac{1}{2}(16.27)(3.05)\left(0.73 + 6.1 + \frac{3.05}{3}\right) + (16.27)(6.1)\left(0.73 + \frac{6.1}{2}\right)\right. \\ + \left(\frac{1}{2}\right)(6.1)(35.97 - 16.27)\left(0.73 + \frac{6.1}{3}\right) + \left(\frac{1}{2}\right)(35.97 + 17.1)(0.73)\underset{\substack{\uparrow \\ \text{Approximate}}}{\left(\frac{0.73}{2}\right)}\end{array}\right]$$

$$= \mathbf{88.95\ kN/m}$$

Free Earth Support Method for Penetration of Clay

Figure 9.34 shows an anchored sheet-pile wall penetrating a clay soil and with a granular soil backfill. The diagram of pressure distribution above the dredge line is similar to that shown in Figure 9.12. From Eq. (9.42), the net pressure distribution below the dredge line (from $z = L_1 + L_2$ to $z = L_1 + L_2 + D$) is

$$\sigma_6 = 4c - (\gamma L_1 + \gamma' L_2)$$

For static equilibrium, the sum of the forces in the horizontal direction is

$$P_1 - \sigma_6 D = F$$

where

P_1 = area of the pressure diagram ACD
F = anchor force per unit length of the sheet pile wall

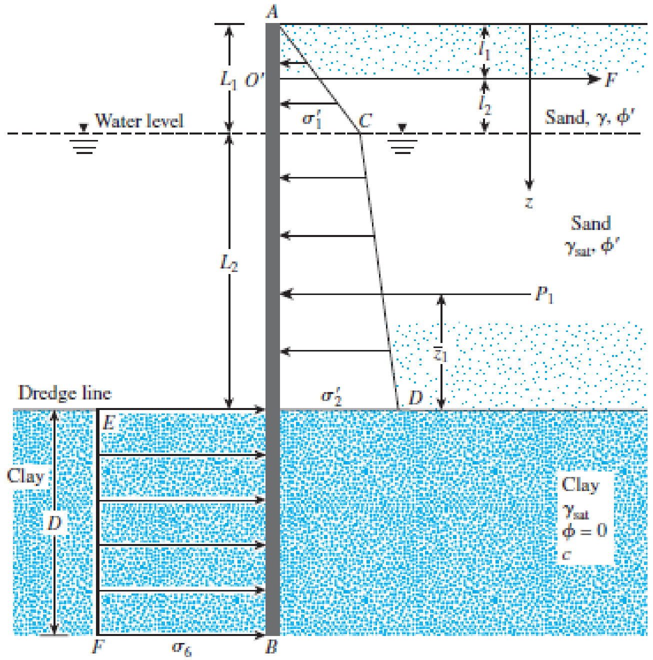


Figure 9.34 Anchored sheet-pile wall penetrating clay

Again, taking the moment about O' produces

$$P_1(L_1 + L_2 - l_1 - \bar{z}_1) - \sigma_6 D\left(l_2 + L_2 + \frac{D}{2}\right) = 0$$

Simplification yields

$$\sigma_6 D^2 + 2\sigma_6 D(L_1 + L_2 - l_1) - 2P_1(L_1 + L_2 - l_1 - \bar{z}_1) = 0 \qquad (9.85)$$

Equation (9.85) gives the theoretical depth of penetration, D.

Example 9.10

In Figure 9.34, let $L_1 = 3$ m, $L_2 = 6$ m, and $l_1 = 1.5$ m. Also, let $\gamma = 17$ kN/m^3, $\gamma_{sat} = 20$ kN/m^3, $\phi' = 35°$, and $c = 41$ kN/m^2.

- **a.** Determine the theoretical depth of embedment of the sheet-pile wall.
- **b.** Calculate the anchor force per unit length of the wall.

Solution

Part a

We have

$$K_a = \tan^2\left(45 - \frac{\phi'}{2}\right) = \tan^2\left(45 - \frac{35}{2}\right) = 0.271$$

and

$$K_p = \tan^2\left(45 + \frac{\phi'}{2}\right) = \tan^2\left(45 + \frac{35}{2}\right) = 3.69$$

From the pressure diagram in Figure 9.36,

$$\sigma'_1 = \gamma L_1 K_a = (17)(3)(0.271) = 13.82 \text{ kN/m}^2$$

$$\sigma'_2 = (\gamma L_1 + \gamma' L_2)K_a = [(17)(3) + (20 - 9.81)(6)](0.271) = 30.39 \text{ kN/m}^2$$

$$P_1 = \text{areas } 1 + 2 + 3 = 1/2(3)(13.82) + (13.82)(6) + 1/2(30.39 - 13.82)(6)$$
$$= 20.73 + 82.92 + 49.71 = 153.36 \text{ kN/m}$$

and

$$\bar{z}_1 = \frac{(20.73)\left(6 + \frac{3}{3}\right) + (82.92)\left(\frac{6}{2}\right) + (49.71)\left(\frac{6}{3}\right)}{153.36} = 3.2 \text{ m}$$

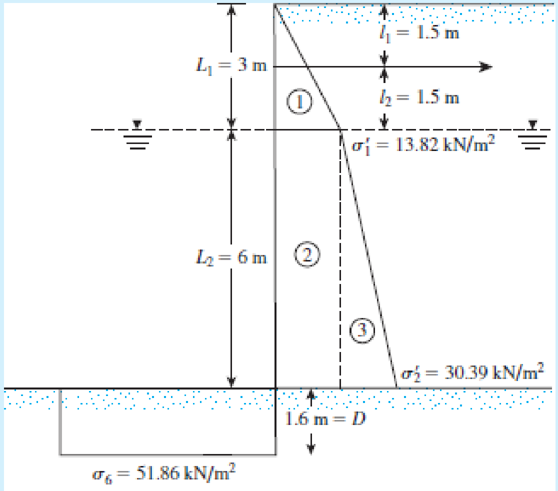
From Eq. (9.85),

$$\sigma_6 D^2 + 2\sigma_6 D(L_1 + L_2 - l_1) - 2P_1(L_1 + L_2 - l_1 - \bar{z}_1) = 0$$

$$\sigma_6 = 4c - (\gamma L_1 + \gamma' L_2) = (4)(41) - [(17)(3) + (20 - 9.81)(6)] = 51.86 \text{ kN/m}^2$$

So,

$$(51.86)D^2 + (2)(51.86)(D)(3 + 6 - 1.5) - (2)(153.36)(3 + 6 - 1.5 - 3.2) = 0$$



Free earth support method, sheet pile penetrating into clay

or

$$D^2 + 15D - 25.43 = 0$$

Hence,

$$D \approx \mathbf{1.6\ m}$$

Part b

From Eq. (9.84),

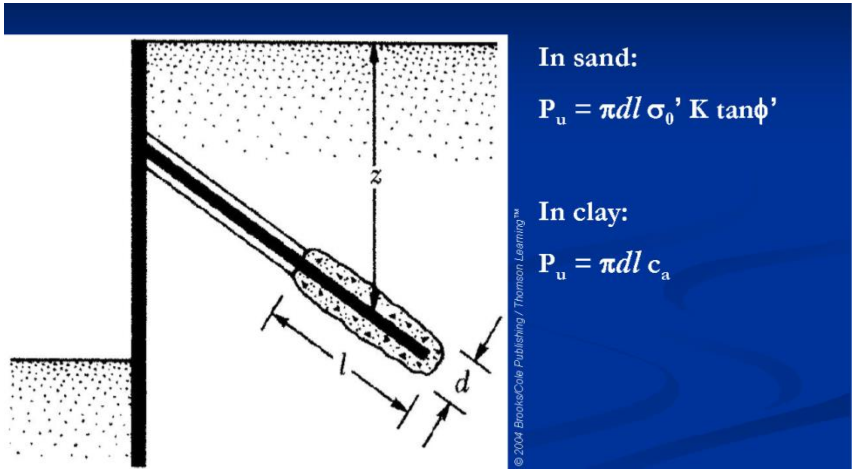
$$F = P_1 - \sigma_6 D = 153.36 - (51.86)(1.6) = \mathbf{70.38\ kN/m}$$

Prestressed anchors

Sections 9.9 through 9.15 gave an analysis of anchored sheet-pile walls and discussed how to obtain the force *F* per unit length of the sheet-pile wall that has to be sustained by the anchors. The current section covers in more detail the various types of anchor generally used and the procedures for evaluating their ultimate holding capacities.

The general types of anchor used in sheet-pile walls are as follows:

1. Anchor plates and beams (deadman)
2. Tie backs
3. Vertical anchor piles
4. Anchor beams supported by batter (compression and tension) piles



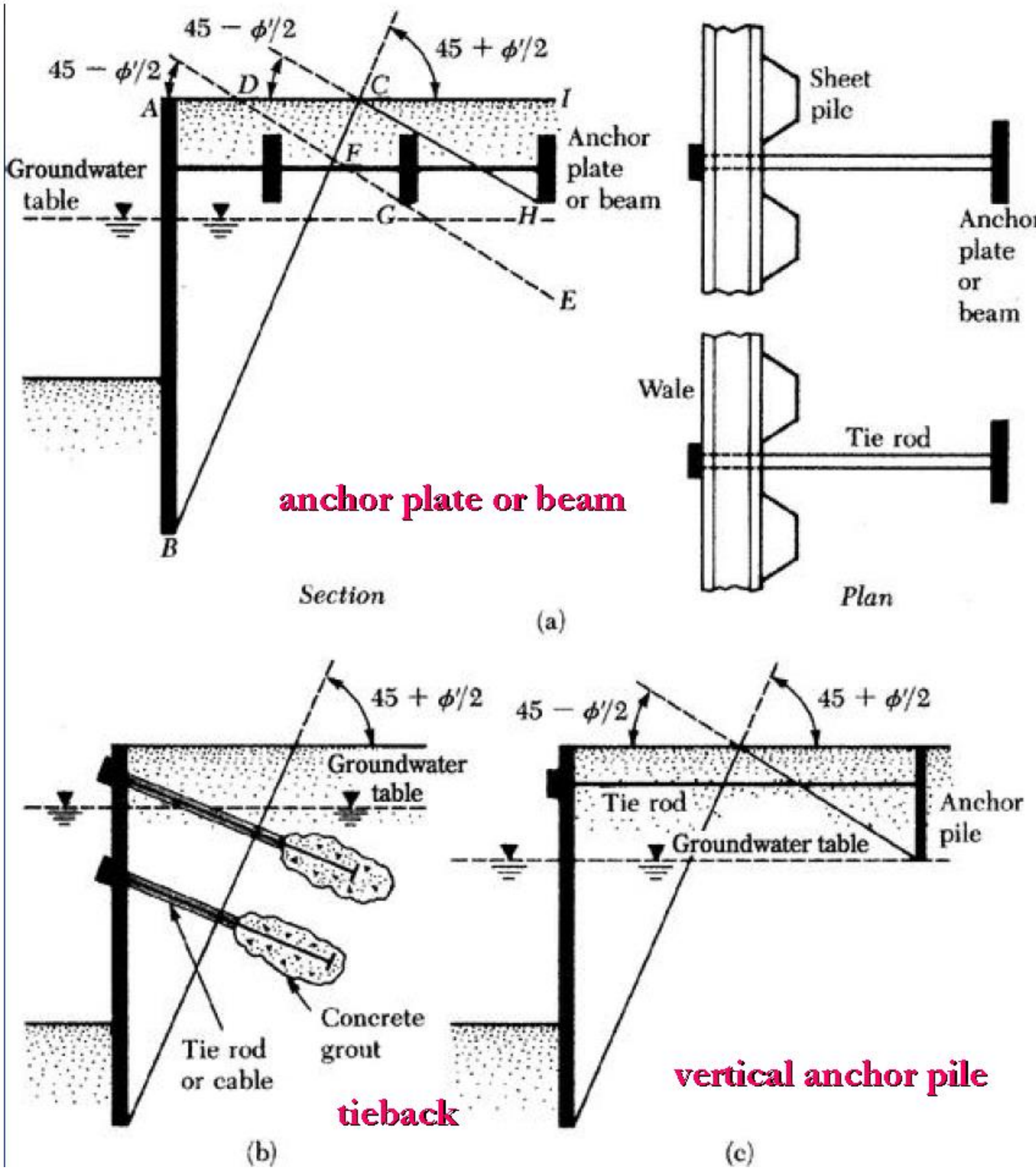
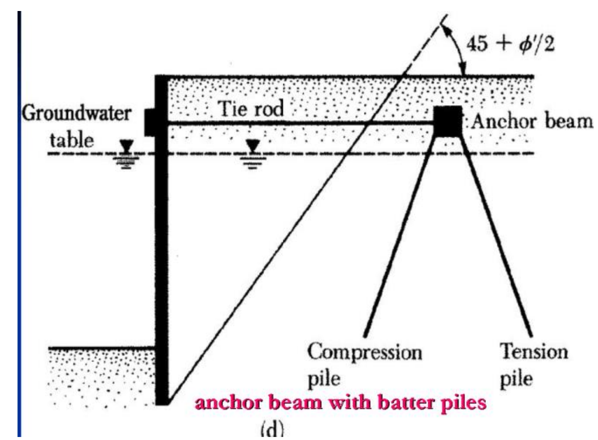
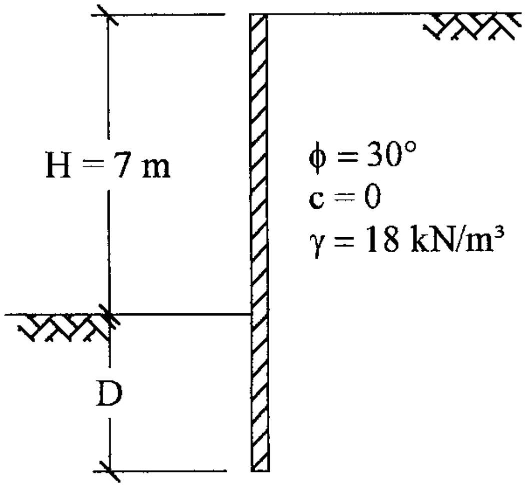


Figure 9.37 Various types of anchoring for sheet-pile walls: (a) anchor plate or beam; (b) tieback; (c) vertical anchor pile; (d) anchor beam with batter piles



Example-1



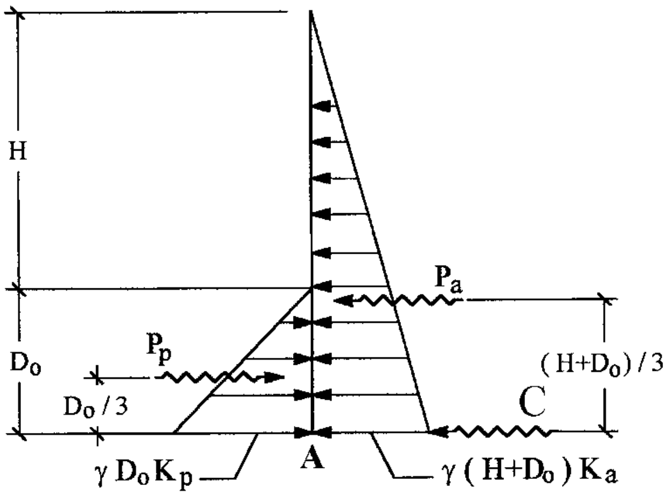
For the sheet pile wall penetrating sandy soil
Determine the theoretical depth of embedment, *D*?

$$K_a = tg^2(45 - \frac{\phi}{2}) = 0.33 \qquad K_p = tg^2(45 + \frac{\phi}{2}) = 3$$

Sum moment of the forces per unit length of wall about point A =0

$$\sum M_A = 0 \qquad P_a \frac{(4 + D_o)}{3} - P_p \frac{D_o}{3} = 0$$

$$0.297(4 + D_o)^2 \frac{(4 + D_o)}{3} - 2.7(D_o)^2 \frac{D_o}{3} = 0$$ eşitliği elde edilir.



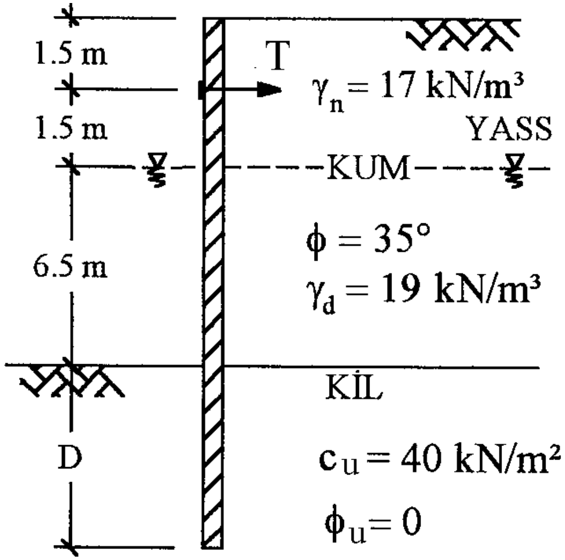
<u>The above equation will be solved for</u> D_o by trial and error method:

D_o = 3.7 m.

The actual depth of penetration is increased by about 20 to 30%.

D = 1.2 D_o = 1.2 x 3.7 = **4.44 m**

Örnek-2

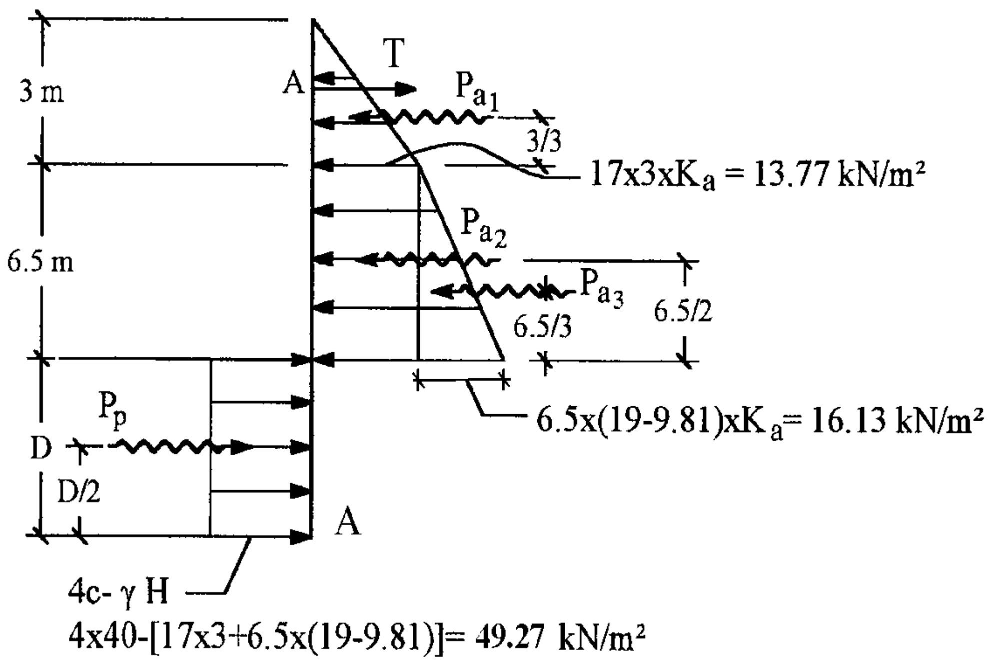


Şekilde verilen serbest zemin mesnetli ankrajlı palplanşta;

a) Güvenli çakma derinliğini bulunuz

b) Ankraj kuvvetini hesaplayınız

- Çözüm için önce palplanşa gelen zemin itkisinin belirlenmesi gerekir.
- Bunun için şekilde verilen gerilme dağılışından yararlanılabilir. Sistemin çözümü için P_{a1}, P_{a2}, P_{a3} ve P_p kuvvetlerinin belirlenmesi ve A noktasına göre moment alınması gerekmektedir.



$$K_a = tg^2\left(45 - \frac{\phi}{2}\right) = 0.27$$

$$P_{a1} = 13.77x\frac{3}{2} = 20.66 \quad kN/m$$

$$P_{a2} = 13.77x6.5 = 89.51 \quad kN/m$$

$$P_{a3} = 16.13x\frac{6.5}{2} = 52.42 \quad kN/m$$

$$P_p = 49.27D$$

Örnek-2 devamı

Moment denge eşitliğinden $\sum \mathrm{M_A} = 0$ yazılırsa

$$20.66\left(3x\frac{2}{3}-1.5\right)+89.51\left(\frac{6.5}{2}+1.5\right)+52.42\left(6.5x\frac{2}{3}+1.5\right)-49.27D\left(\frac{D}{2}+8\right)=0$$

$\Rightarrow D = 1.7\,m$ olarak bulunur.

Güvenli çakma derinliğini bulmak için bulunan çakma derinliği % 20 – 40 oranında artırılır.

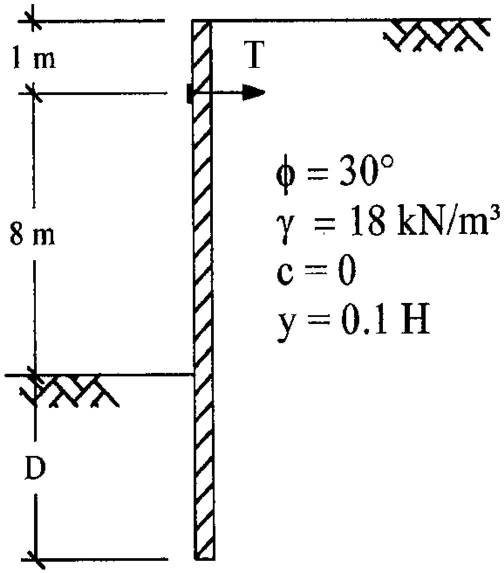
Buna göre ;

$D_{güv}$ = 1.2 x D = **2.04 m** olarak bulunur.

Ankraj kuvvetinin belirlenmesi için yatay denge eşitliğinden yararlanılır.

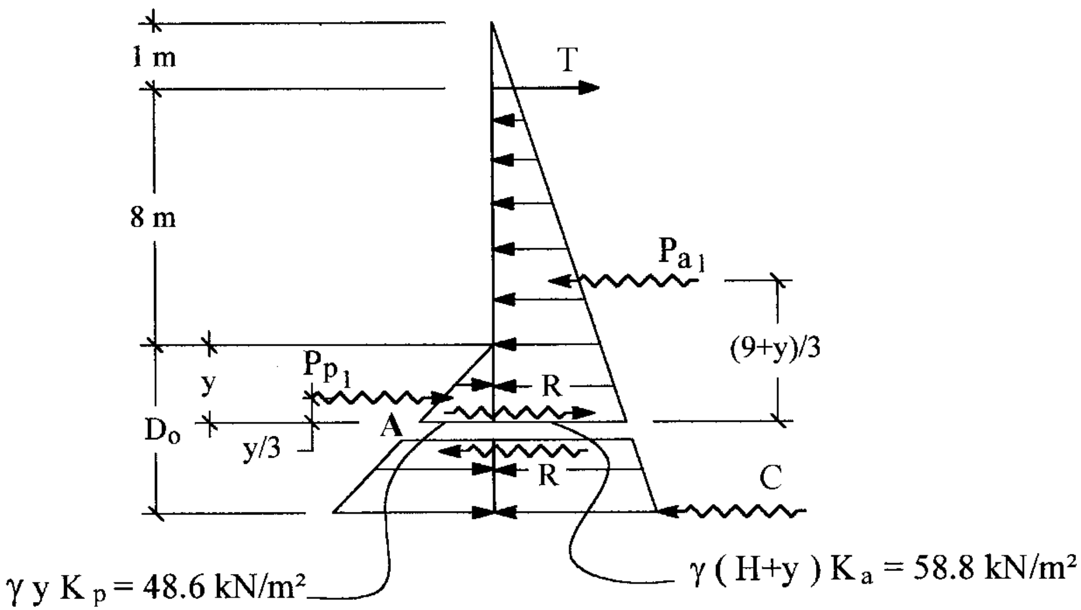
$$\sum H = 0 \qquad P_{a1} + P_{a2} + P_{a3} = P_p + T \Rightarrow T = 20.66 + 89.51 + 52.42 - 49.27x1.7 = 79.02\ \mathrm{kN/m}$$

Örnek-3



Şekilde verilen ankrajlı tutulu zemin mesnetli palplanş duvarın güvenli çakma derinliğini hesaplayınız.

- Çözüm için önce palplanşa gelen zemin itkisinin belirlenmesi gerekir.
- Bunun için aşağıdaki şekilde verilen gerilme dağılışından yararlanılabilir. Gerilme dağılışı incelenirse yazılabilecek iki denge eşitliğine karşın üç bilinmeyen (T, C, D_o) olduğu görülür.
- Bu durumda sistemi çözebilmek için sistemin dönme noktasından kesilmesi gerekir.

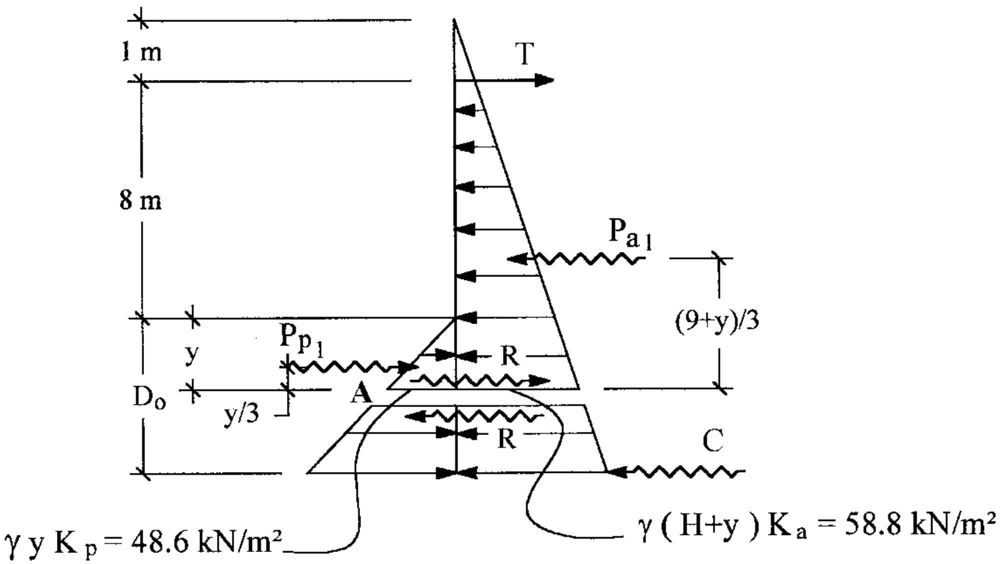


$$y = 0.1H = 0.1x9 = 0.9m$$

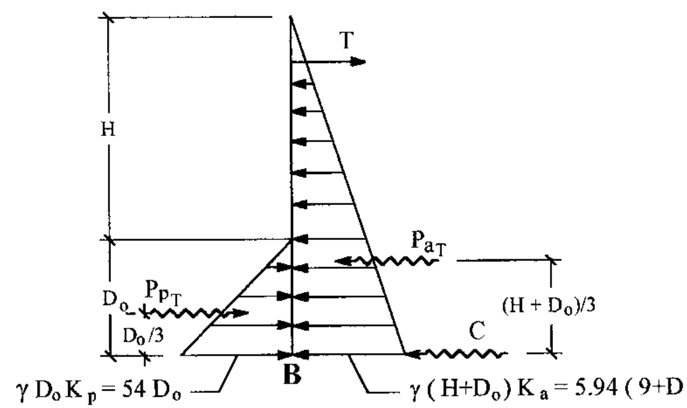
$$K_a = tg^2\left(45 - \frac{30}{2}\right) = 0.33$$

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

Örnek-3 devamı



Önce hesapta kullanılacak kuvvetleri belirleyelim.



<u>Dönme noktasına kadarki kesimde</u>

$$P_{a1} = 58.81\frac{9.9}{2} = 291.11 \text{ kN/m²}$$

$$P_{p1} = 48.6\frac{0.9}{2} = 21.87 \text{ kN/m²}$$

<u>Tüm ankraj derinliği boyunca</u>

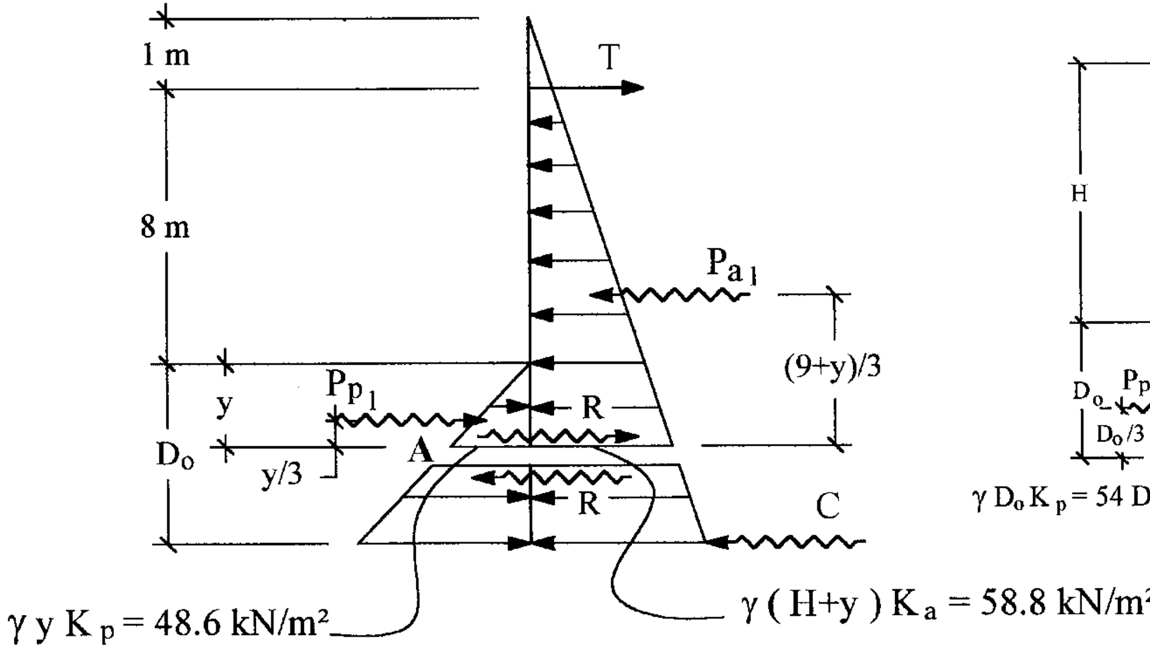
$$P_{aT} = 5.94\frac{(9 + D_o)^2}{2} = 2.97(9 + D_o)^2$$

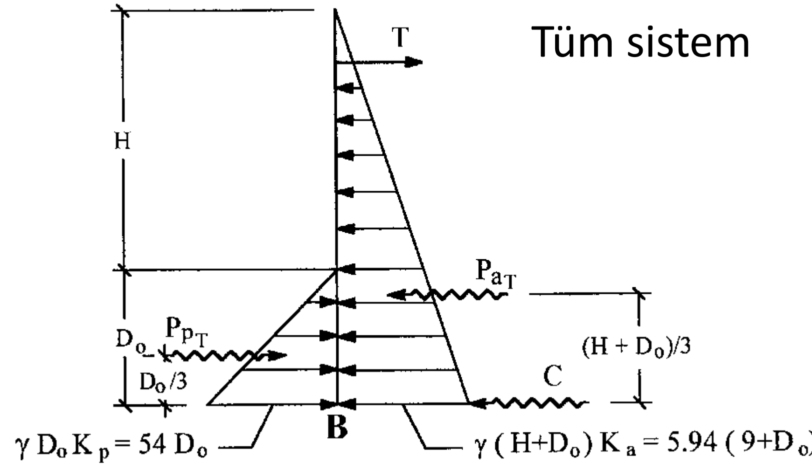
$$P_{pT} = 54\frac{(D_o)^2}{2} = 27(D_0)^2$$

Üst parça için $\sum M_A = 0$ $\quad Tx(8 + y) + P_{p1}x\left(\frac{y}{3}\right) - P_{a1}x\left(\frac{9 + y}{3}\right) = 0 \Rightarrow Tx8.9 + 21.87x0.3 - 291.11x3.3 = 0$

$$\Rightarrow T = 107.2 \text{ kN/m}$$

Örnek-3 devamı





Tüm sistem

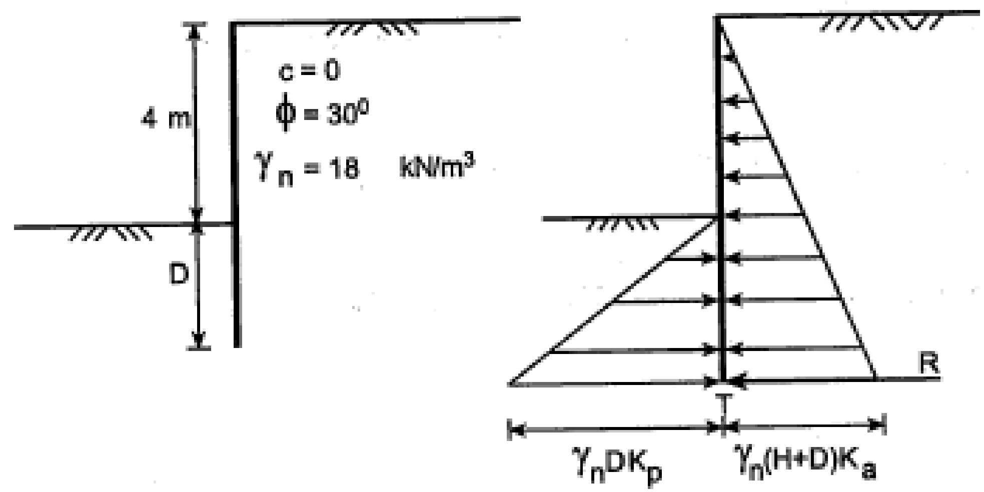
$$\text{Tüm sistem için} \quad \sum M_B = 0 \quad \mathrm{Tx}(8+\mathrm{D_o}) + \mathrm{P_{pT}}\mathrm{x}\left(\frac{\mathrm{D_o}}{3}\right) - \mathrm{P_{aT}}\mathrm{x}\left(\frac{9+\mathrm{D_o}}{3}\right) = 0$$

$$= 107.2(8+\mathrm{D_o}) + 27(\mathrm{D_o})^2\left(\frac{\mathrm{D_o}}{3}\right) - 2.97(9+\mathrm{D_o})^2\left(\frac{9+\mathrm{D_o}}{3}\right) = 0$$

Denklemi elde edilir.
Görüldüğü gibi bu eşitlik D_o'a bağlı üçüncü derecedendir.
Çözüm için deneme yanılma yönteminden yararlanılır. Çözümden;
D_o = 0.9 m olarak bulunur. Buradan çakma derinliği;
D = 1.2 x D_o = 1.2 x 0.9 = 1.08 m, güvenli çakma derinliği ise ;
$D_{güv}$ = 1.2 x D = 1.08 x 1.2 = **1.3 m** olarak bulunur.

Örnek-4

Kum zeminde konsol olarak inşa edilen palplanş perdenin güvenli çakma derinliğini belirleyiniz.



Çözüm

Konsol palplanş perdesinin önünde pasif, arkasında aktif yanal basınçlar oluşur (Şekil 12.78).

$$K_a = \tan^2(45 - 30/2) = 0.333,\ K_p = \tan^2(45 + 30/2) = 3$$

T noktasına göre moment denge denklemini yazalım.

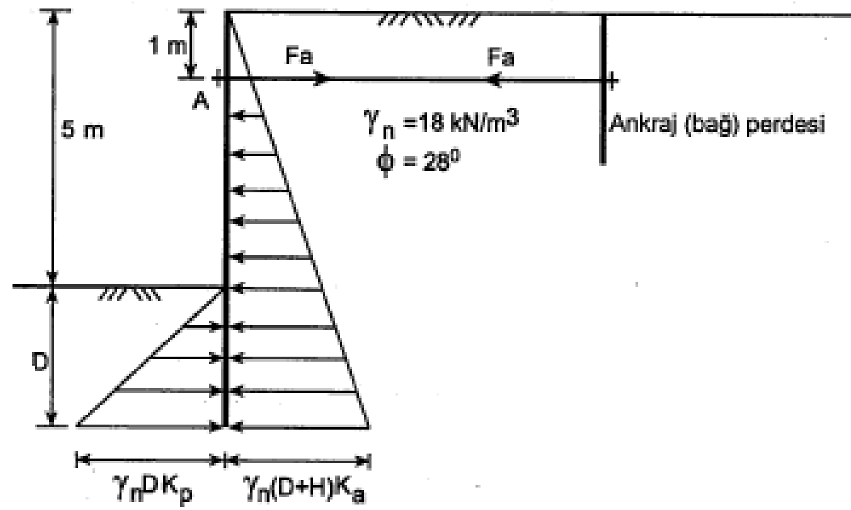
$$\frac{1}{2}\gamma_n D^2 K_p \times \frac{D}{3} = \frac{1}{2}\gamma_n (D+H)^2 K_a \times \frac{(D+H)}{3}$$

$$D = 3.70 \text{ m}, \quad D_{em} = 3.70 \times 1.25 = 4.63 \text{ m}$$

$$L = H + D_{em} = 4 + 4.63 = 8.63 \text{ m}$$

Örnek-5

Kum zeminde serbest mesnetli ankrajlı olarak inşa edilen palplanş perdenin güvenli çakma derinliğini belirleyiniz.



Çözüm

Perdenin önünde pasif, arkasında aktif durum oluşur.

$$K_a = \tan^2(45 - 28/2) = 0.36,\ K_p = \tan^2(45 + 28/2) = 2.77$$

A noktasına göre moment denge denklemi yazılırsa,

$$\frac{1}{2}\gamma_n D^2 K_p (5 + D - D/3 - 1) = \frac{1}{2}\gamma_n (D+5)^2 \left[\frac{2(D+5)}{3} - 1\right] \times K_a$$

$$D = 2.15\,\text{m}, D_{em} = 2.15 \times 1.2 = 2.60\,\text{m}$$

$$L = 2.60 + 5 = 7.60\,\text{m}$$

bulunur.