GROUND ANCHOR SYSTEMS

DESIGN OF RETAINING STRUCTURES

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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

Anchor plates and beams are generally made of cast concrete blocks. (See Figure 9.37a.) The anchors are attached to the sheet pile by *tie-rods*. A *wale* is placed at the front or back face of a sheet pile for the purpose of conveniently attaching the tie-rod to the wall. To protect the tie rod from corrosion, it is generally coated with paint or asphaltic materials.

In the construction of *tiebacks*, bars or cables are placed in predrilled holes (see Figure 9.37b) with concrete grout (cables are commonly high-strength, prestressed steel tendons). Figures 9.37c and 9.37d show a vertical anchor pile and an anchor beam with batter piles.

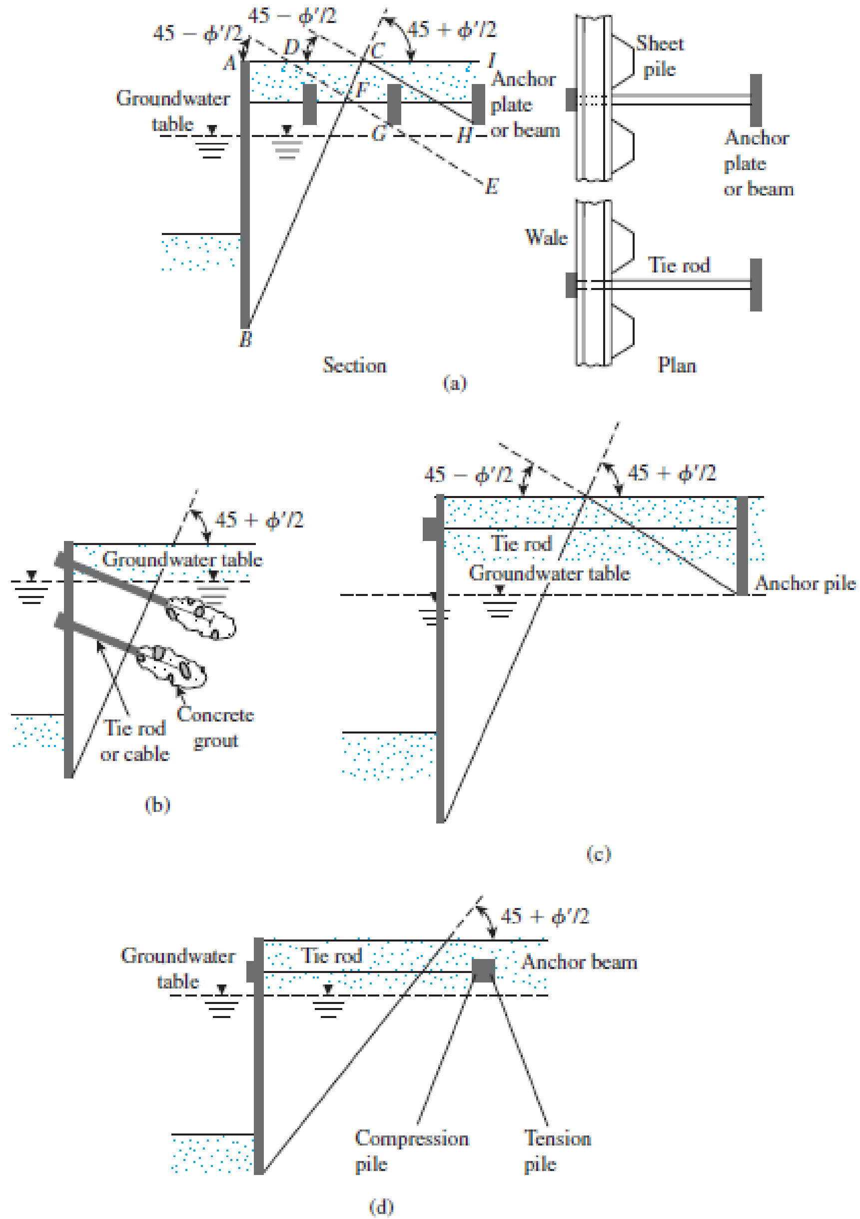

Figure 9.37 Various types of anchoring for sheet-pile walls: (a) anchor plate or beam; (b) tieback; (c) vertical anchor pile; (d) anchor beam with batter piles


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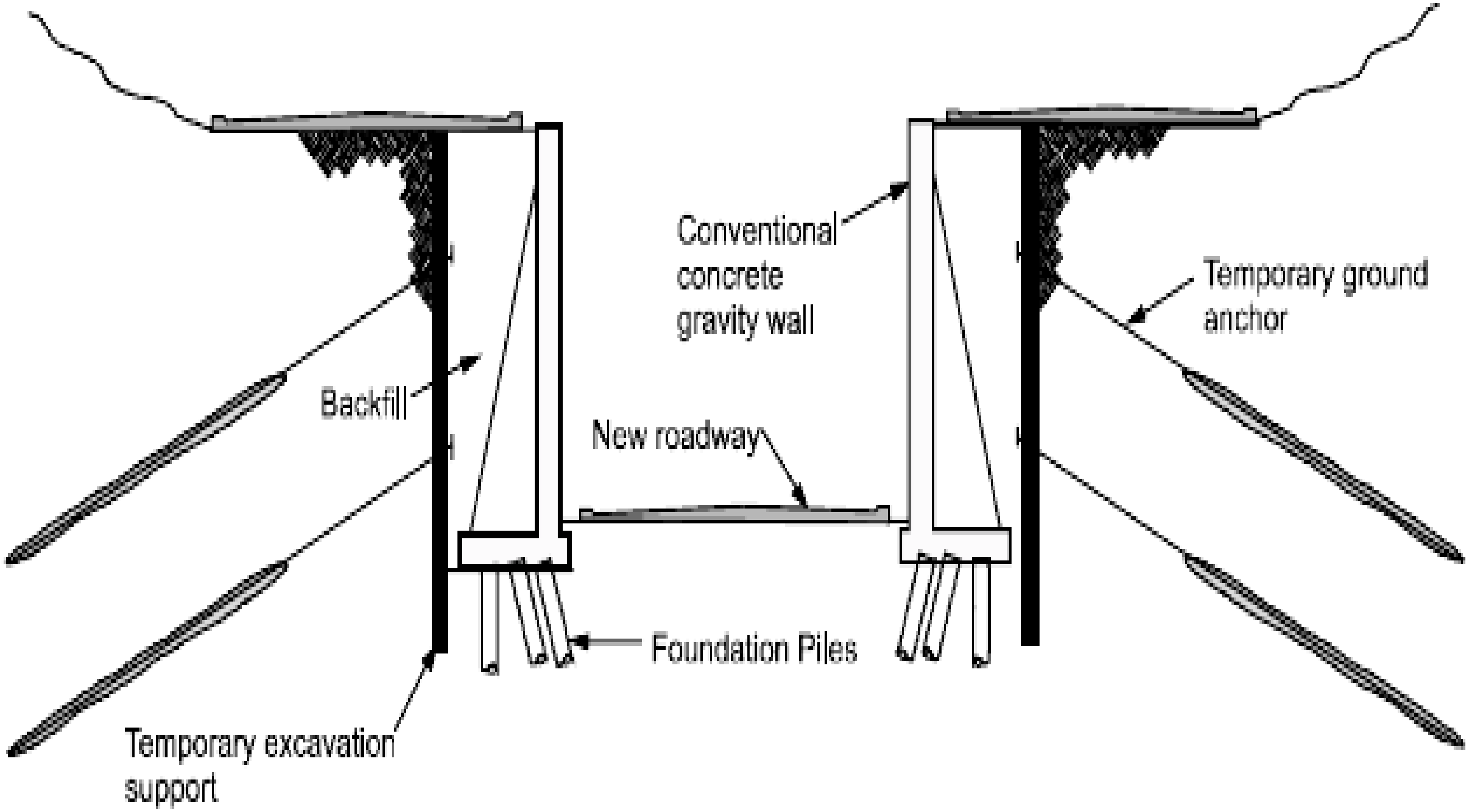
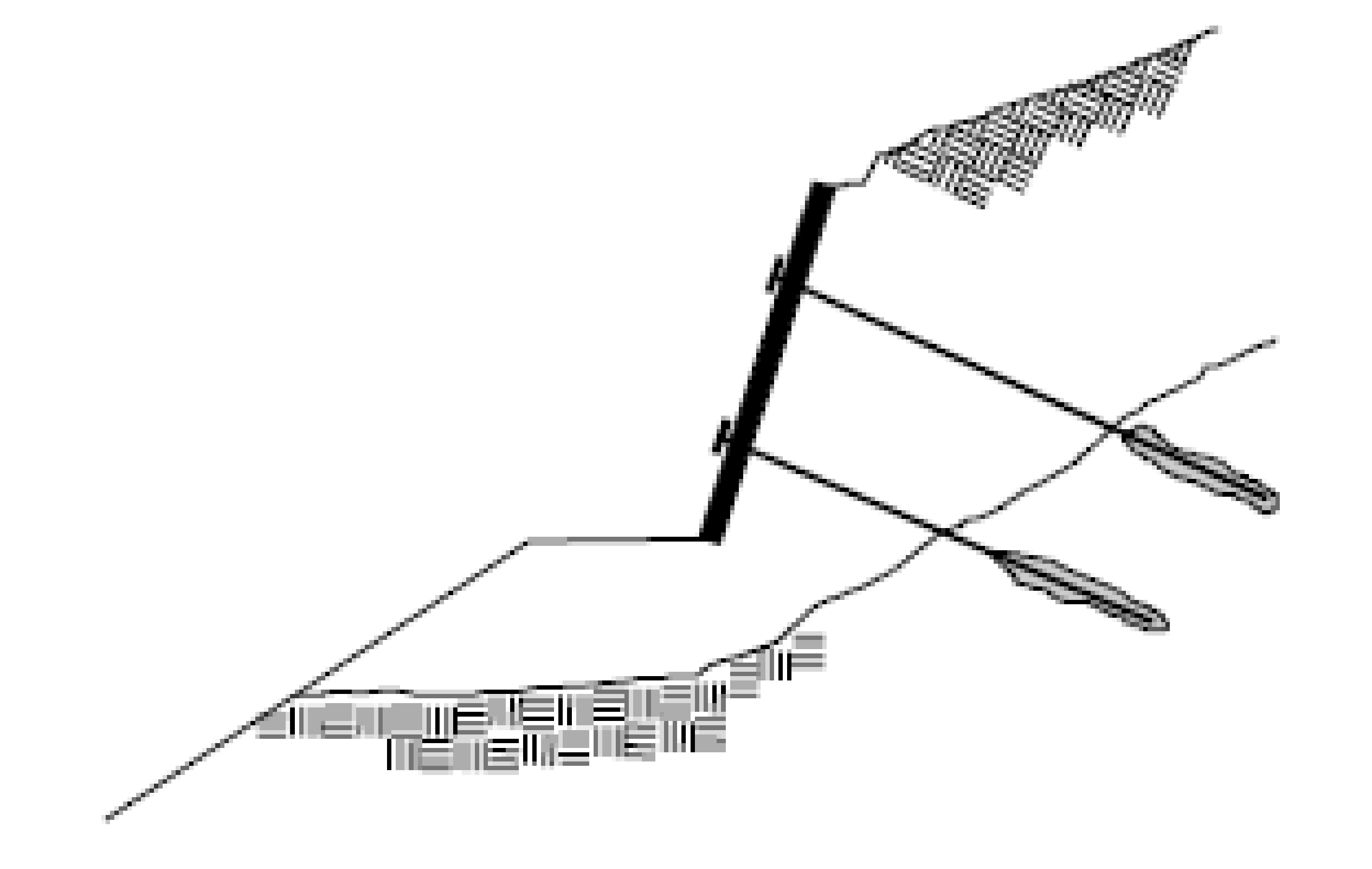
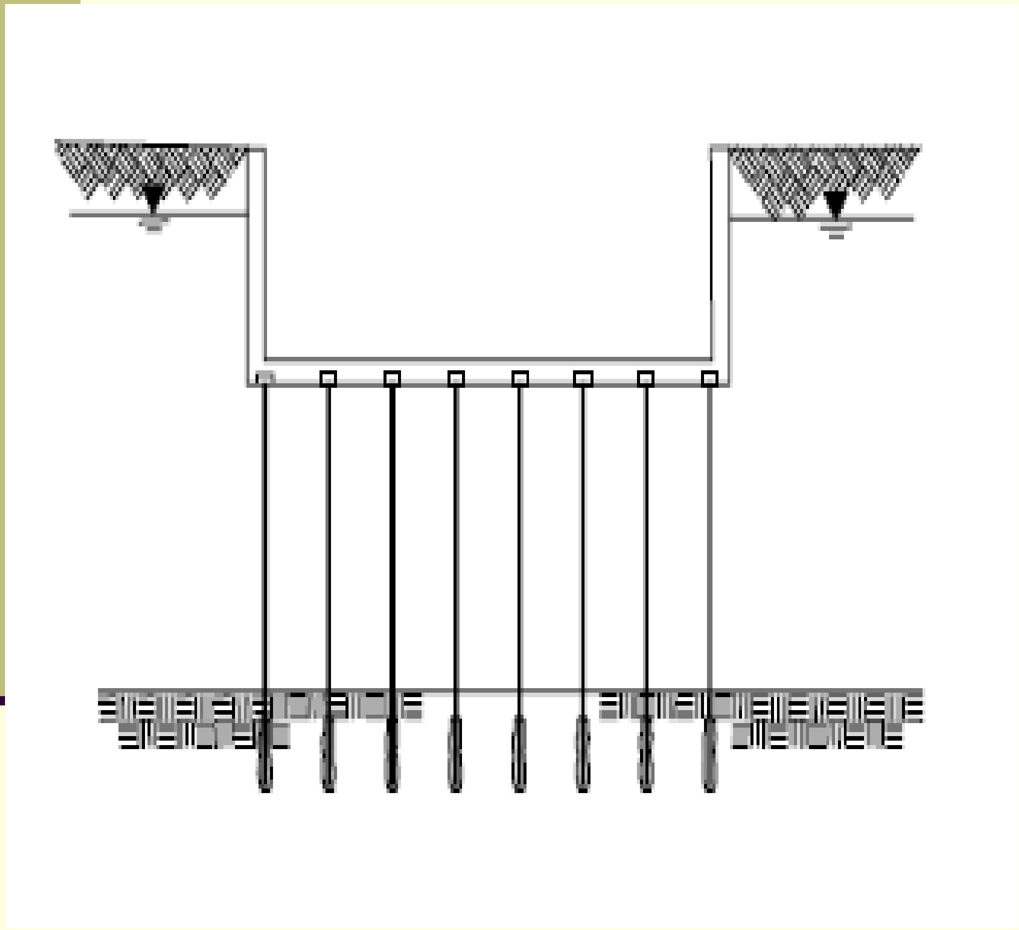


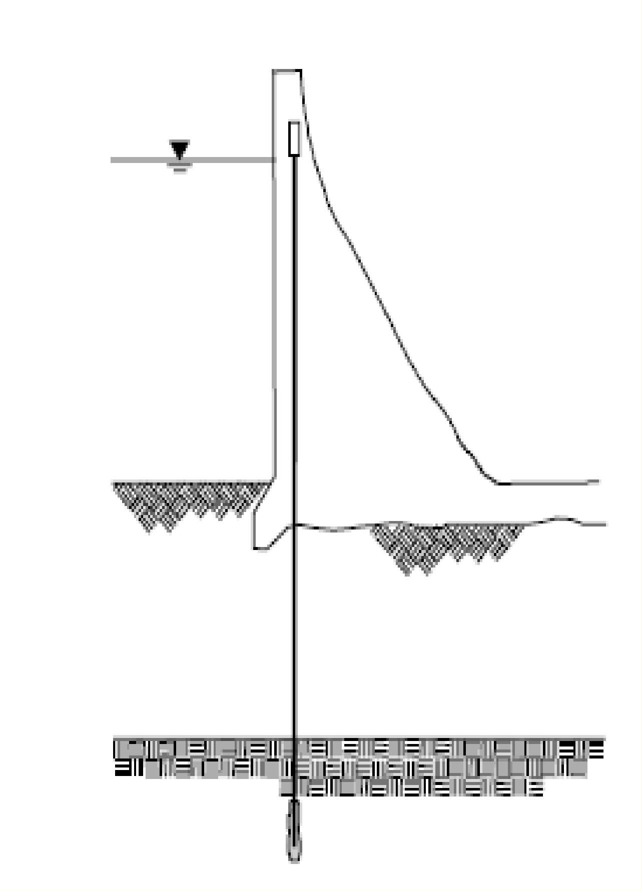
a-) Highway Retaining Structures



b-) Improvement Slope Stability



b-) To reinforce/support the excavation base

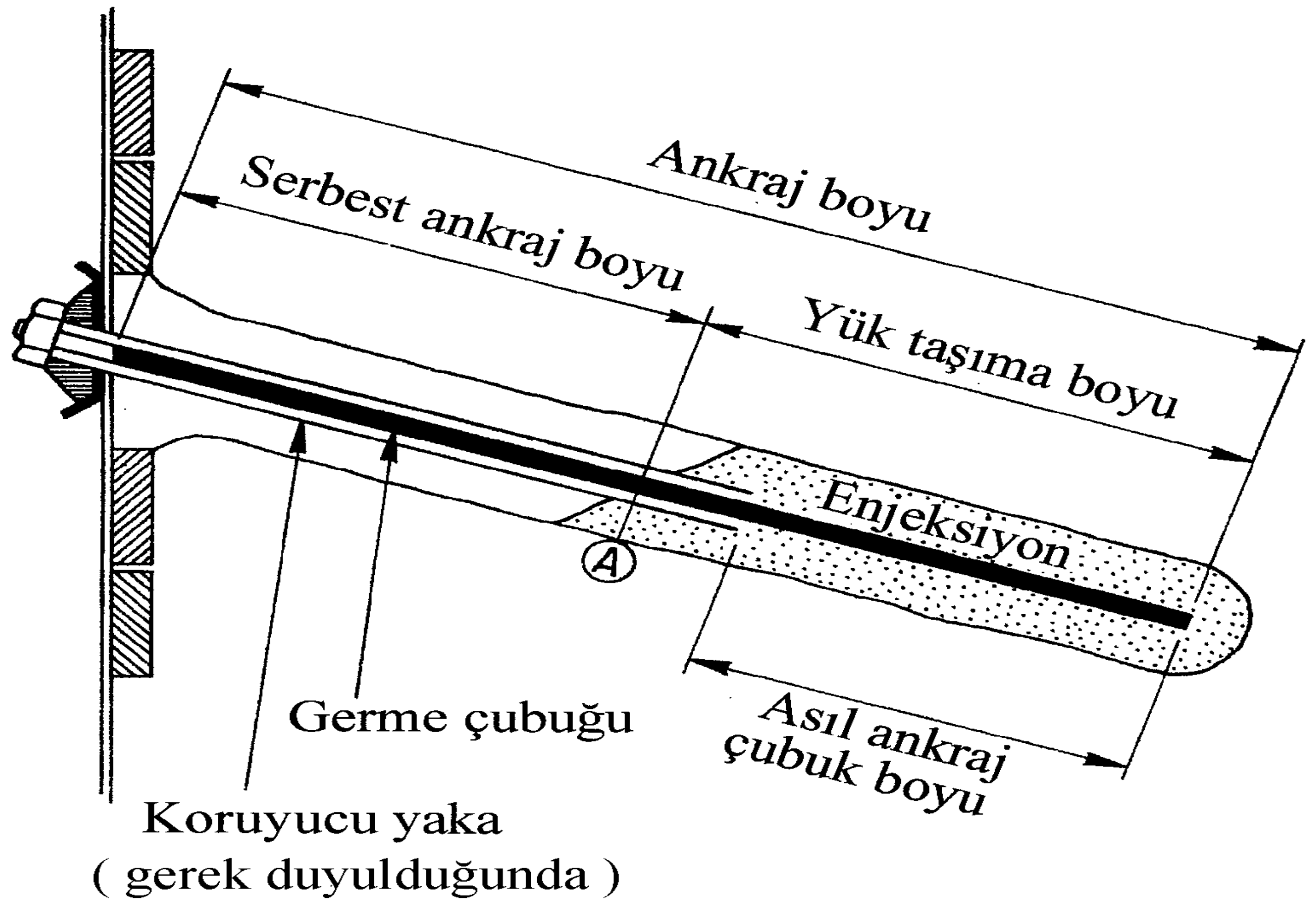


c-) In the construction of concrete Dams

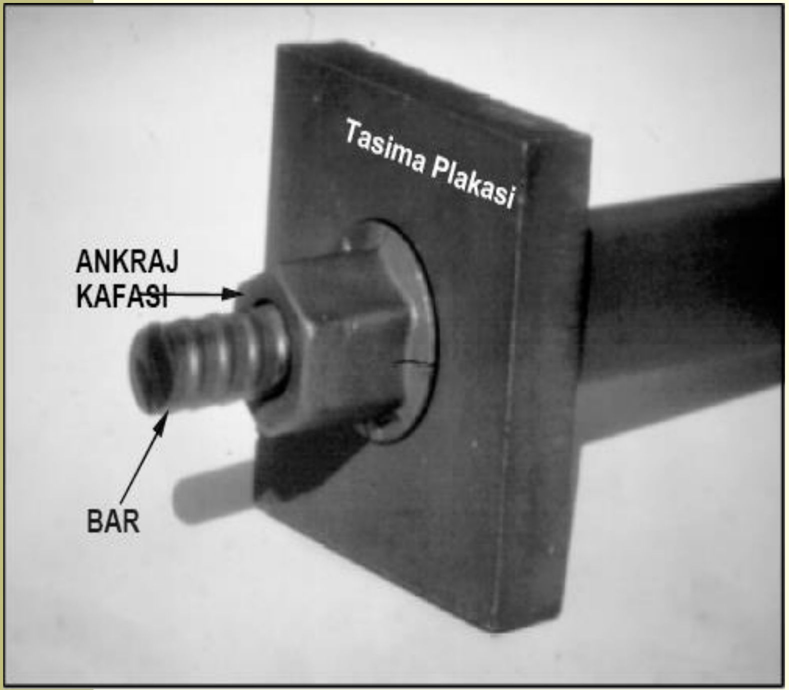
Structural Member of Anchors

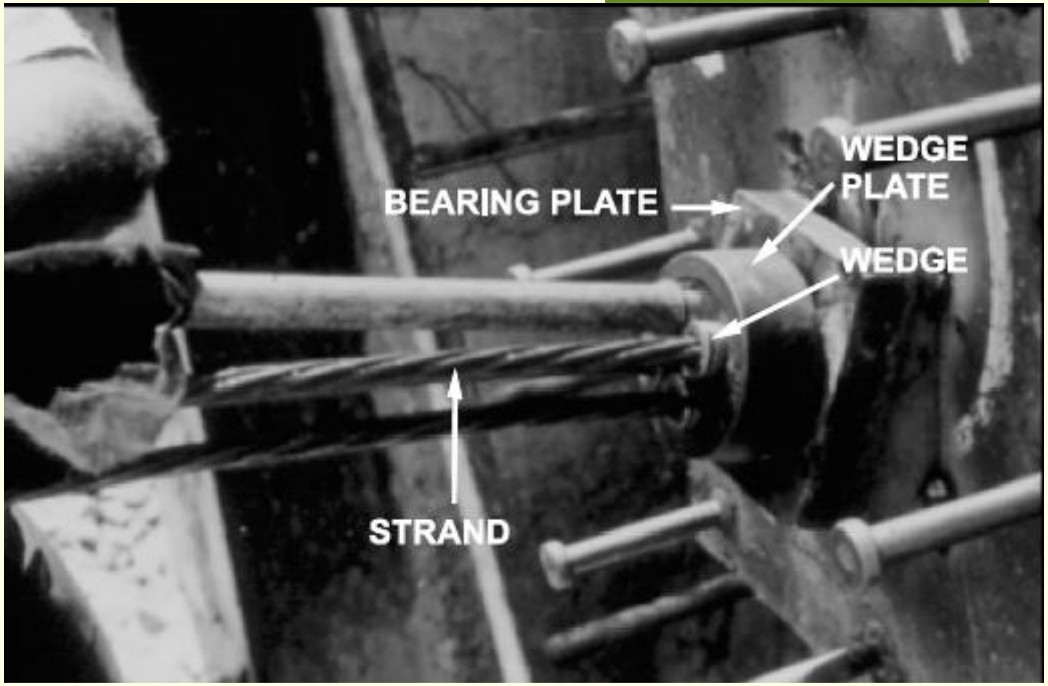
- Anchor add,
- Tie rod or cable (Free length) ,
- Anchor root

Structural Member of Anchors



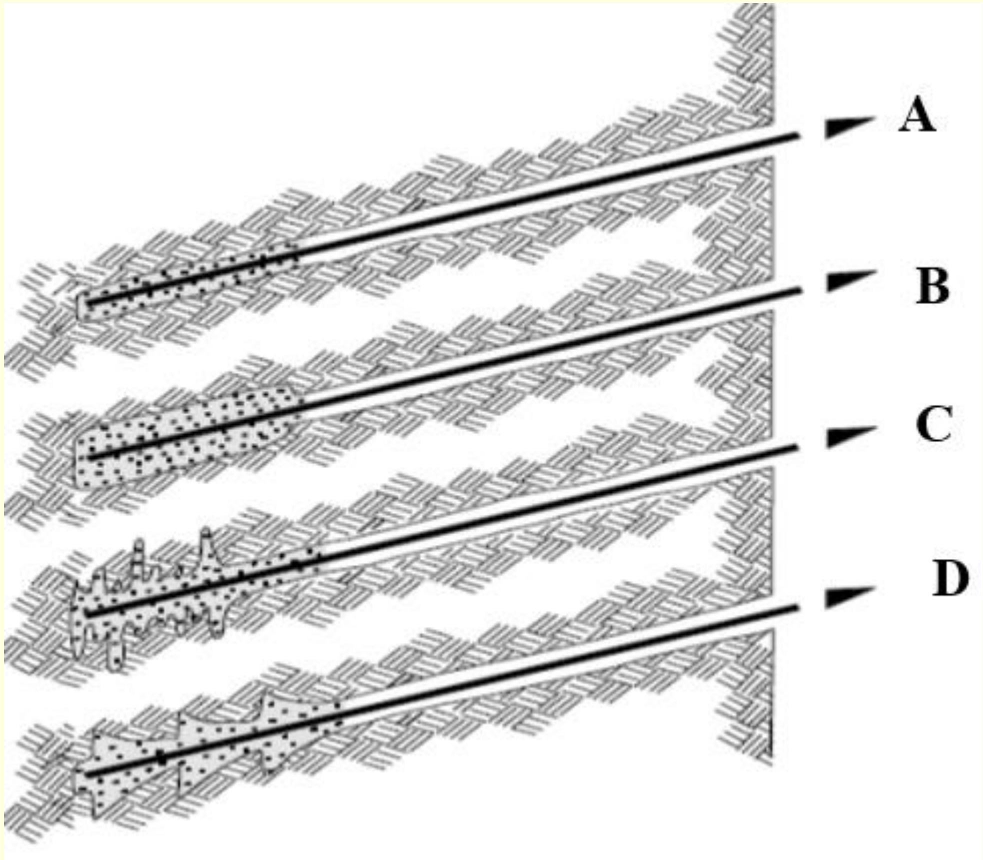
Anchor Head





- Anchor Head is composed of Bearing plate, strand, Wedge Plate

Different Types of Anchors



Rock Anchors

Design Steps For an anchored wall

Table 4. Typical design steps for an anchored wall (modified after FHWA-RD-81-150, 1982)

Step 1.	Establish project requirements including all geometry, external loading conditions (temporary and/or permanent, seismic, etc.), performance criteria, and construction constraints.
Step 2.	Evaluate site subsurface conditions and relevant properties of in situ soil and rock.
Step 3.	Evaluate design properties, establish design factors of safety, and select level of corrosion protection.
Step 4.	Select lateral earth pressure distribution acting on back of wall for final wall height. Add appropriate water, surcharge, and seismic pressures and evaluate total lateral pressure. A staged construction analysis may be required for walls constructed in marginal soils.
Step 5.	Calculate horizontal ground anchor loads and wall bending moments. Adjust vertical anchor locations until an optimum wall bending moment distribution is achieved.

Design Steps For an anchored wall

Step 6.	Evaluate required anchor inclination based on right-of-way limitations, location of appropriate anchoring strata, and location of underground structures.
Step 7.	Resolve each horizontal anchor load into a vertical force component and a force along the anchor.
Step 8.	Evaluate horizontal spacing of anchors based on wall type. Calculate individual anchor loads.
Step 9.	Select type of ground anchor.
Step 10.	Evaluate vertical and lateral capacity of wall below excavation subgrade. Revise wall section if necessary.
Step 11.	Evaluate internal and external stability of anchored system. Revise ground anchor geometry if necessary.
Step 12.	Estimate maximum lateral wall movements and ground surface settlements. Revise design if necessary.
Step 13.	Select lagging. Design walers, facing drainage systems, and connection devices.

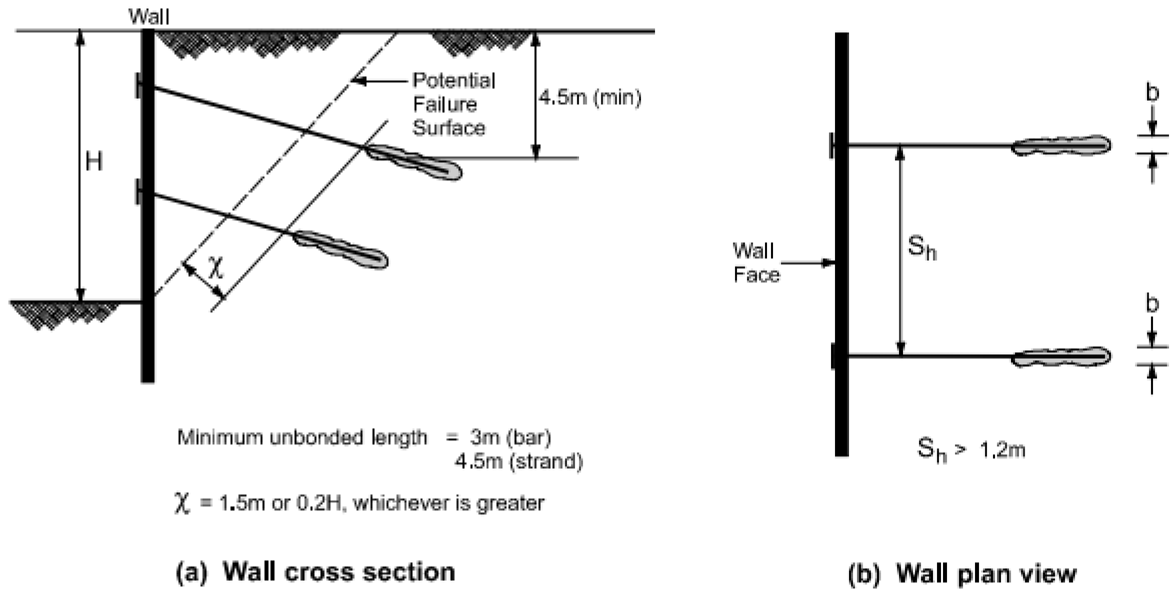
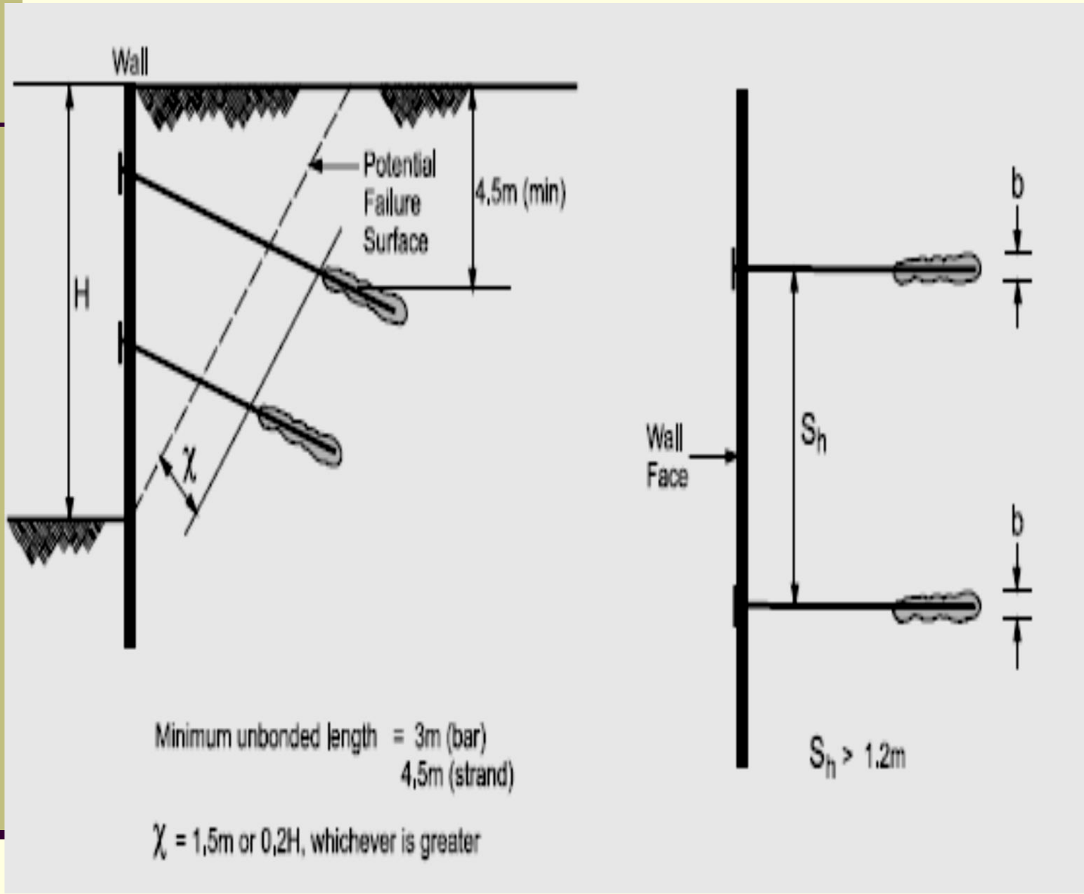


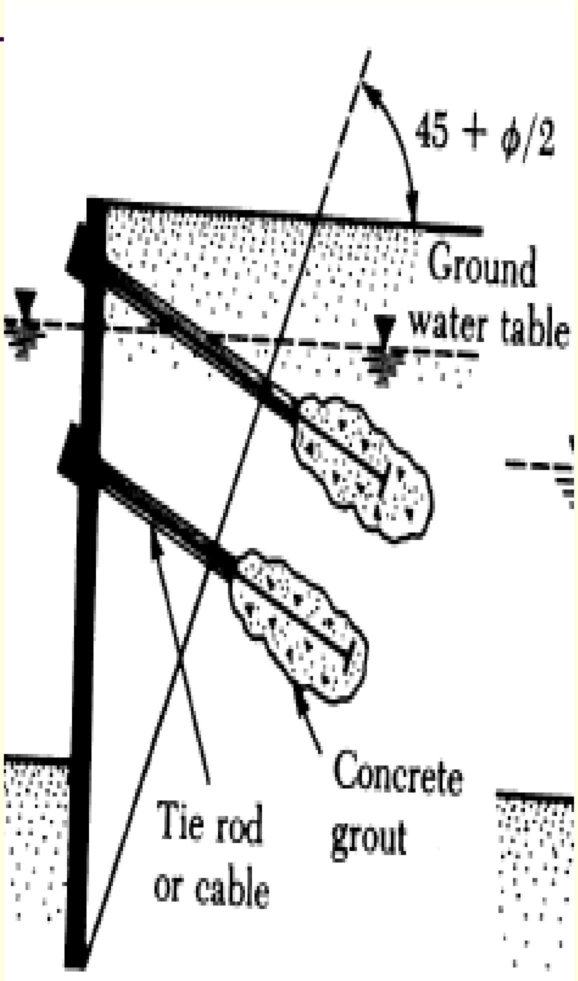
Figure 37. Vertical and horizontal spacing requirements for ground anchors.

Interaction Between the Anchors:

- In order to prevent the interaction between the anchoo roots;
- The distance between the centers of the two adjacent root should not exceed 4D
- In practice, a minimum interval of 1.5m-2.0m is applied.
- The distance between the root of the anchor and any subground structure (foundation, tunnel) must be greater than 3m.

Criteria for Anchor Design





Minimum Free Length of Anchor =4.5 m

Z_c çekme çatlağının belirlenmesi

$$\sigma_a = \gamma z K_a - 2c\sqrt{K_a}$$

where K_a = coefficient of Rankine active pressure

For determining the depth of tensile crack,

$$\sigma_a = 0 = \gamma z_c K_a - 2c\sqrt{K_a}$$

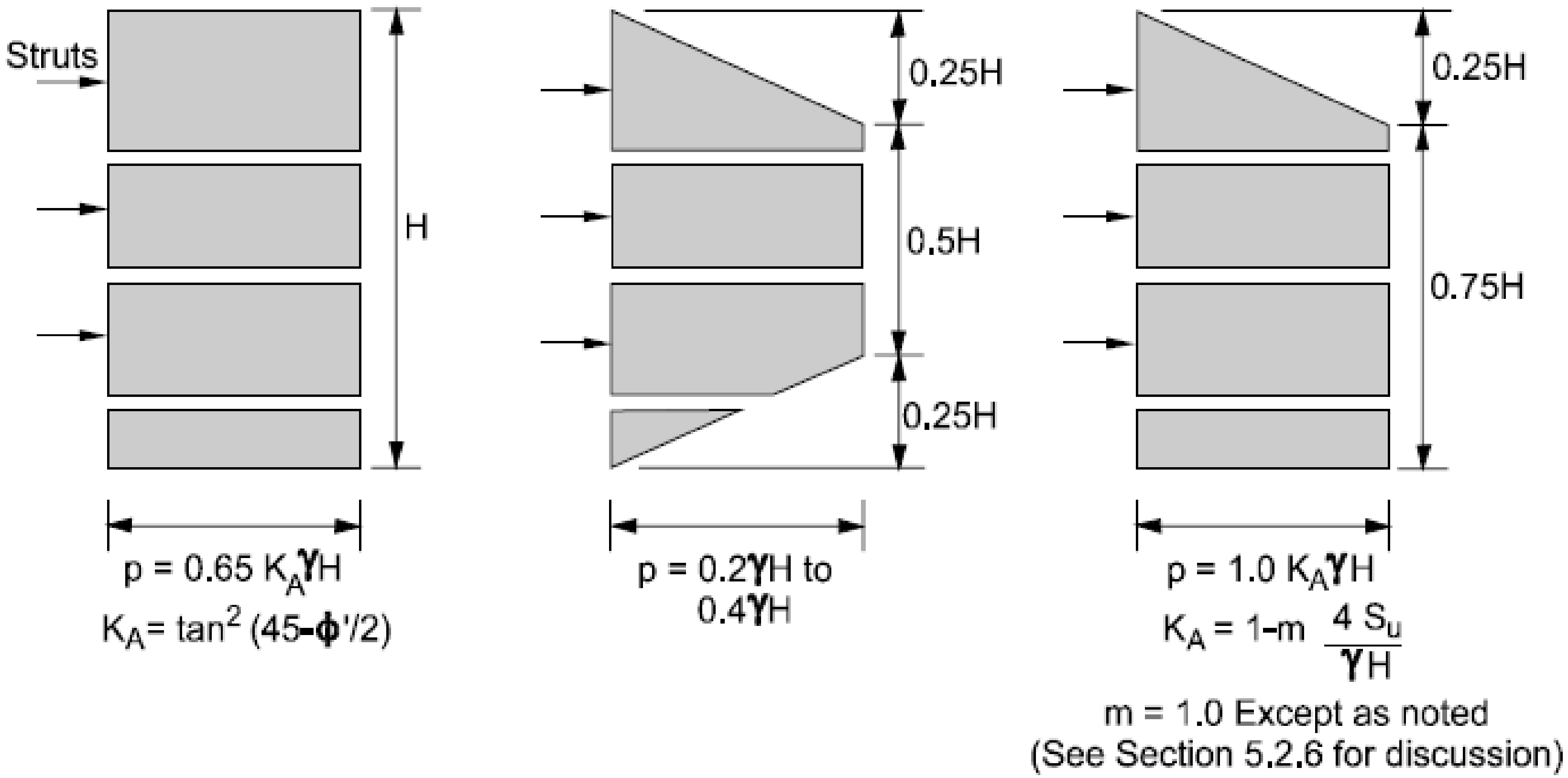
or

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

With $\phi = 0$, $K_a = \tan^2(45 - \phi/2) = 1$, so

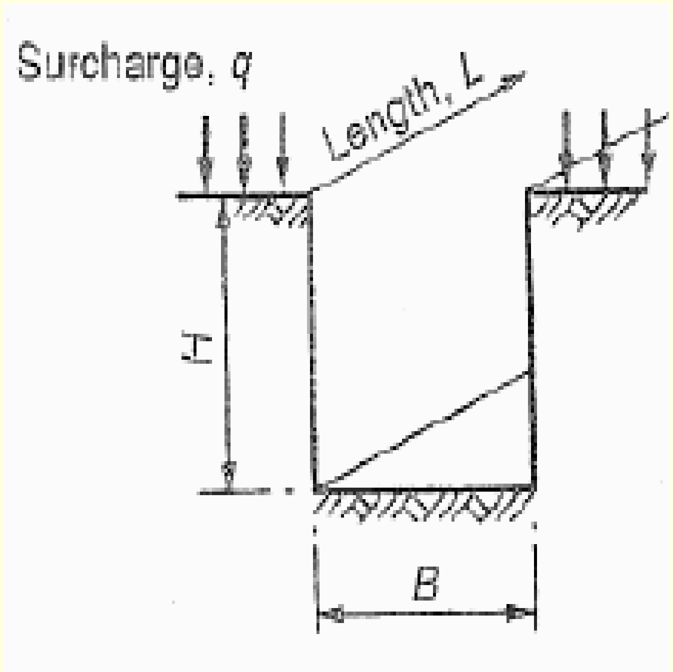
$$z_c = \frac{2c}{\gamma}$$

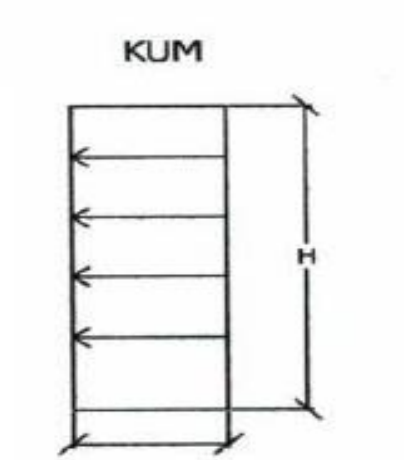
Lateral Earth Pressure Distribution



a-Sands **b- Stiff Clays** **c-Soft to medium stiff clays**

Lateral Earth Pressure Distribution in cohesive and cohesionless soils (Terzaghi and Peck 1967)



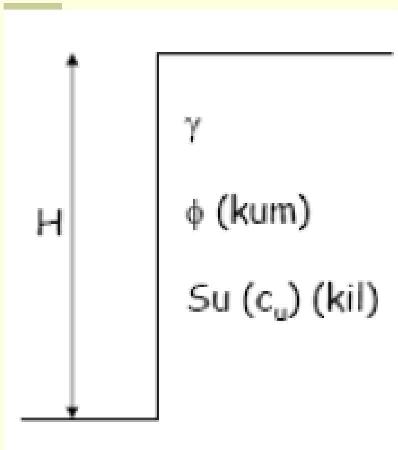


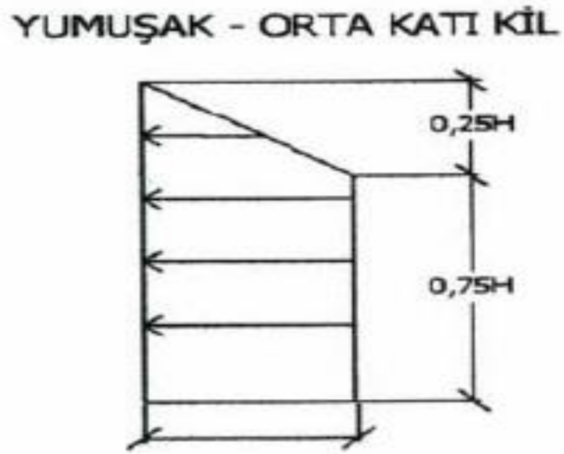
P_a=(0.65)γHK_A

$$P_a = 0.65\gamma HK_A$$

$$K_A = tg^2(45 - \phi'/2)$$

Lateral Earth Pressure Distribution in cohesive and cohesionless soils (Terzaghi and Peck 1967)





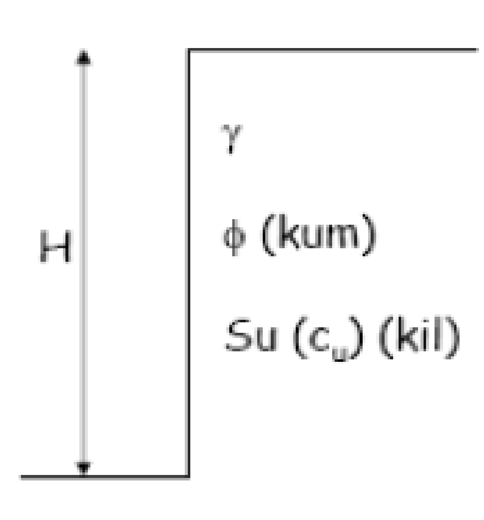
P_a

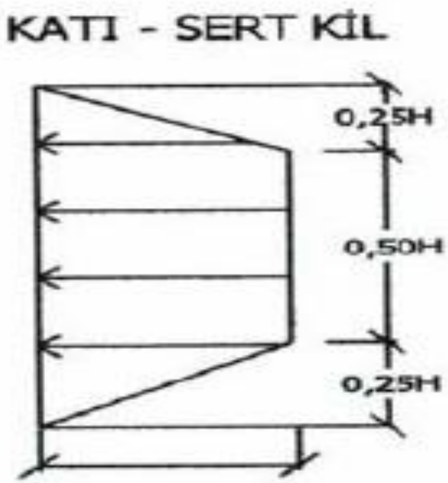
$$N_O = \frac{\gamma H}{c_u} > 6$$

$$P_a = \left(1 - m\frac{4c_u}{\gamma H}\right)\gamma H > 0.25$$

Normal konsolide kilde m=0.4
Aşırı konsolide kilde m=1

Lateral Earth Pressure Distribution in cohesive and cohesionless soils (Terzaghi and Peck 1967)





P_a=(0.2-0.4)γH

$$N_O = \frac{\gamma H}{c_u}$$

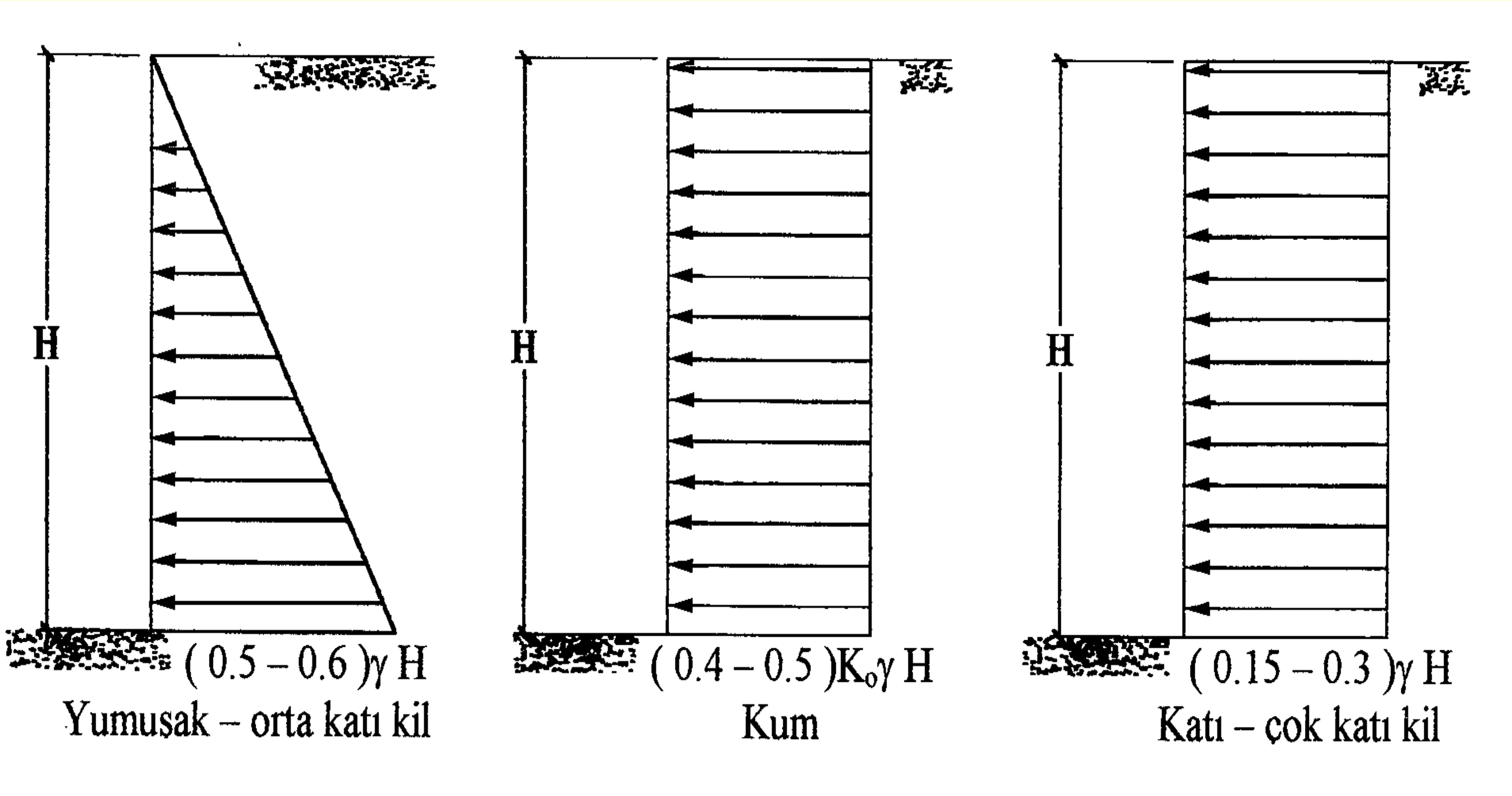
$$N_O < 4$$

$$P_a = 0.2\gamma H - 0.4\gamma H$$

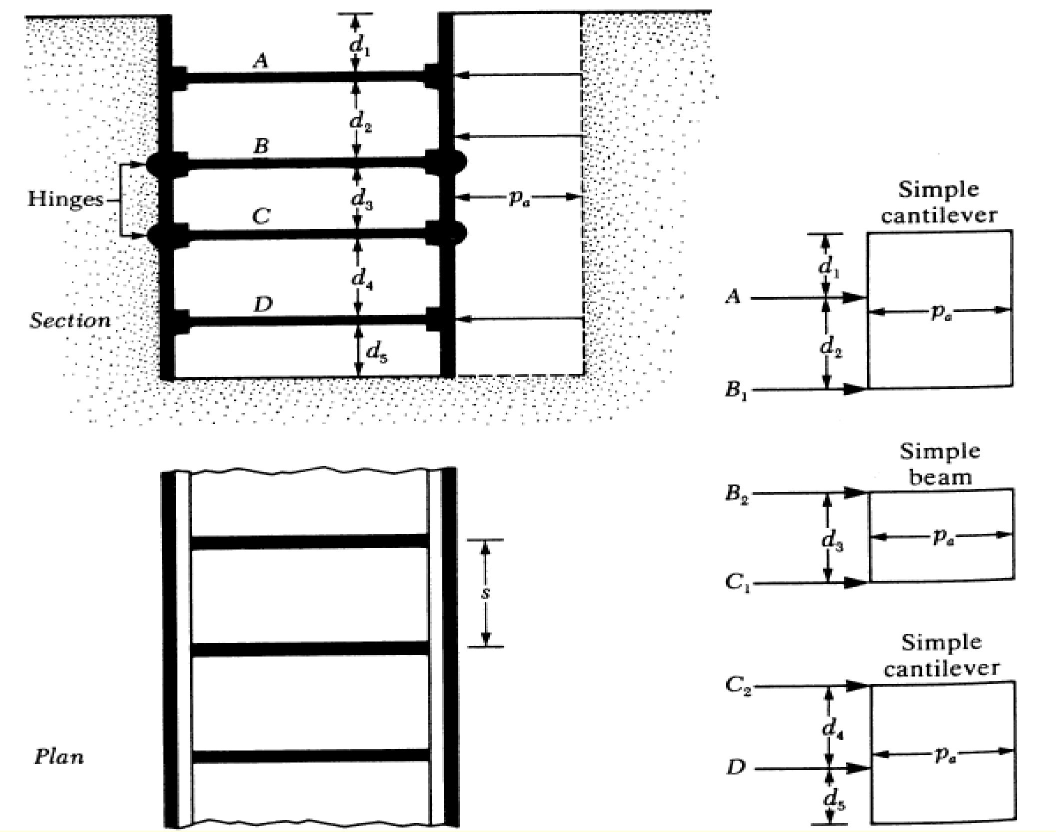
hareketler az ve kısa süreli

inşaatlarda 0.2γH tersi durumda 0.4γH

Lateral Earth Pressure Distribution (NAVFAC)

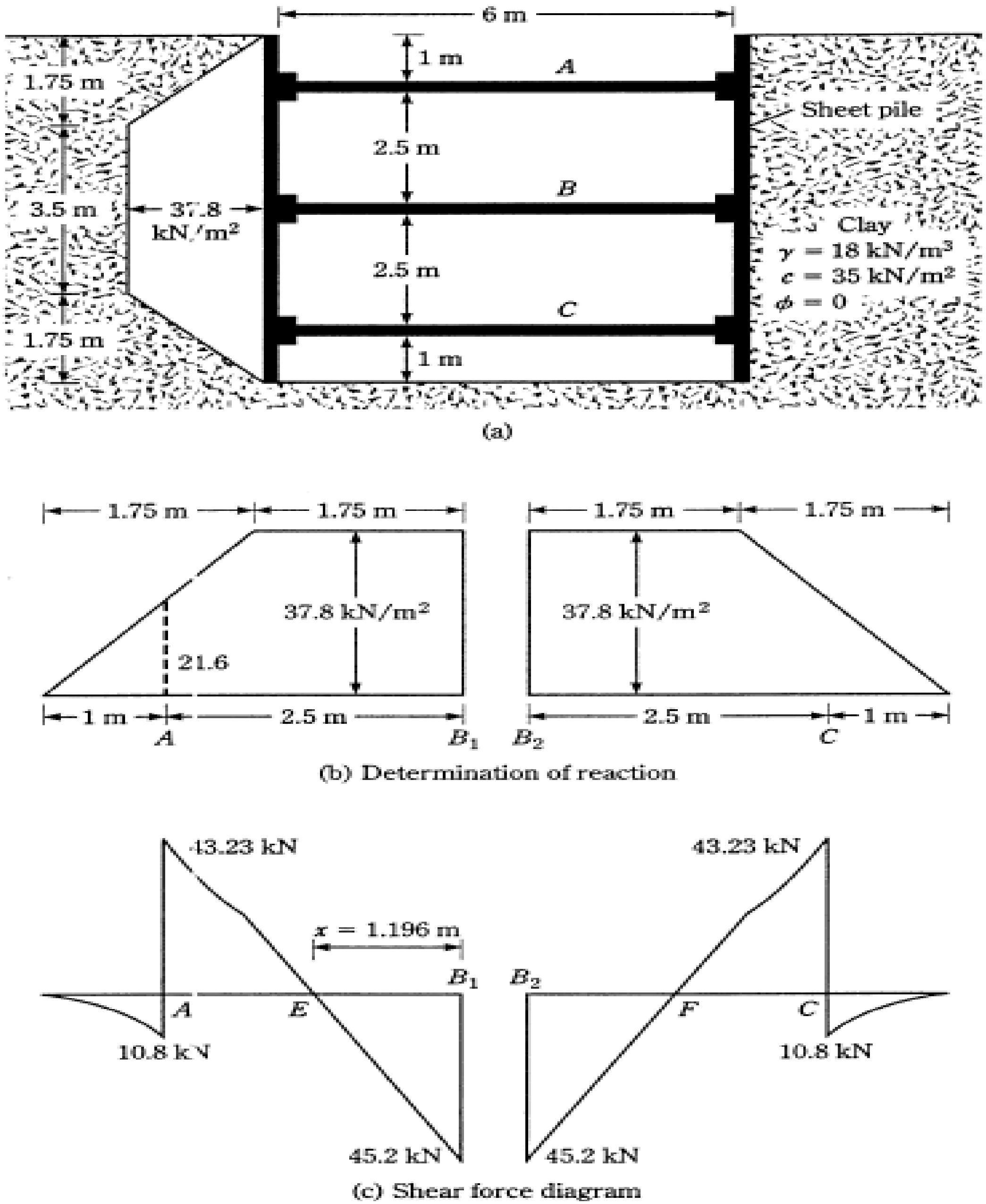


Determination of Anchor Loads



$$P_A = A \times s$$
$$P_B = (B_1 + B_2) \times s$$
$$P_C = (C_1 + C_2) \times s$$
$$P_D = D \times s$$

s= spacing between the struts



(a)

(b) Determination of reaction

(c) Shear force diagram

Anchor Capacity in Granular Soils

Anchor Type B

1st Method

$$P_i = L{*}n{*}\tan\phi'$$

ϕ'= İçsel sürtünme açısı

L= Ankraj kök boyu (m)

n= coefficient based on permeability,injection pressure

$n \approx 400\text{-}600$ kN/m (coarse sands ve gravels $k>10^{-4}$ m/sn)

$n \approx 130\text{-}165$ kN/m (fine sands),$k=10^{-4}\text{-}10^{-6}$ m/sn

Anchor Capacity in Granular Soils

Anchor Type B

2nd method -. Yöntem (Based on Bearing Capcity Theory)

Expanded Diameter =38-61 cm (High permeable soils)

$$P_i = \pi \cdot D \cdot L \cdot \sigma_v' \cdot \tan\phi + \pi/4 \cdot (D^2-d^2) \cdot Nq \cdot \gamma \cdot h$$

- σ_v': Vertical Effective stress in the mid point of root(kPa)
- L : Root length(m)
- ϕ: Internal friction angle
- N_q: Bearing capacity factor
- γ : Unit weight of soil(kN/m^3)
- h : Distance from mid point of root to the ground surface
- D : Root diameter
- d : Diameter of drill hole

- $P_i = K . \pi . D . L . \sigma_v' . \tan\delta + \left(\pi/4 . (D^2 - d^2) . Nq . \gamma . h \right) \longrightarrow$ neglected.
  - $\mathbf{P_i = K . \pi . D . L . \sigma_v' . \tan\delta}$

K= depends on injection Pressure, Relative denisty ve installation type

Soil Type	Pressure	K
Dense sand,Gravel	Low	1.4-2.3
Fine sand and sandy silts	Düşük	0.5-1.0
Dense sand	Düşük	1.4

Anchor Capacity in Cohesive Soils

ANCHOR TYPE D

$$P_i = \pi \cdot D \cdot L \cdot c_u + \pi/4 \cdot (D^2 - d^2) \cdot Nc \cdot c_{ub} + \pi \cdot d \cdot l \cdot c_a$$

- D : Anchor Root Diameter
- L : Root Length
- C_u : Average Undrained Shear Strength along the anchor root
- $N_c = 9$
- c_{ub} : Undrained Shear Strength at the root bottom
- l : shaft length (m)
- c_a : adhesion along the shaft =0.3-0.35 c_u (kPa)

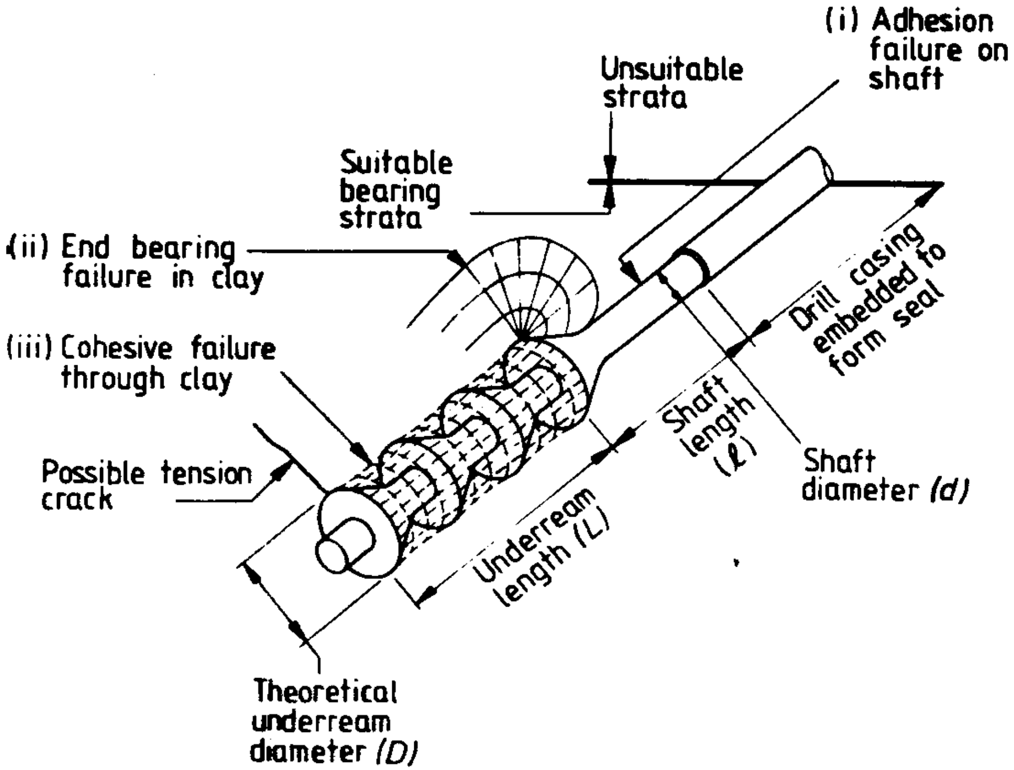


Figure 10. Diagram of multi-underream anchorage at ultimate capacity (after Bassett (1970))

Anchor Capacity in Rocks

- $P_i = \pi \,.\, D \,.\, L \,.\, \delta$
- D : Shaft diameter
- L : Injection length at the rooth
- δ : Strength between injection and Rock Enjeksiyon-kayaç kesiti mukavemeti (Tipik değerler çizelgelerden alınabilir).

Ankrajlar için güvenli taşıma gücü bulunurken en az 2.0(kayaçta=3.) önemli yapılarda ve kalıcı ankrajlarda daha yüksek güvenlik sayısı değerleri kullanılmalıdır.

Bearing Capacity of Anchors

- Anchor Capacity ($P_{root\ capacity}$) = $\dfrac{\sum P_i}{GS}$

Minimum FS=1.5

- Horizontal spacing (s_h)= Anchor capacity*(Cos β)/P_a

P_a= Resultant of lateral earth distribution(kN/m)

Bearing Capacity of Anchors

- For the purposes of preliminary design, the ultimate load transferred from the bond length to the soil may be estimated for a small diameter, straight shaft gravity-grouted anchor from the soil type and density (or SPT blowcount value) (Table 6). The maximum allowable anchor design load in soil may be determined by multiplying the bond length by the ultimate transfer load and dividing by a factor of safety of 2.0.

Bearing Capacity of Anchors

Table 6. Presumptive ultimate values of load transfer for preliminary design of small diameter straight shaft gravity-grouted ground anchors in soil.

Soil type	Relative density/Consistency (SPT range)[1]	Estimated ultimate transfer load (kN/m)
Sand and Gravel	Loose (4-10) Medium dense (11-30) Dense (31-50)	145 220 290
Sand	Loose (4-10) Medium dense (11-30) Dense (31-50)	100 145 190
Sand and Silt	Loose (4-10) Medium dense (11-30) Dense (31-50)	70 100 130
Silt-clay mixture with low plasticity or fine micaceous sand or silt mixtures	Stiff (10-20) Hard (21-40)	30 60

Note: (1) SPT values are corrected for overburden pressure.

Çelik cinsi	Çap (mm)	Spesifik Dayanım (kN)	Alan (mm^2)
Alaşımsız çelik			
Tel	7.0	60.4	38.5
7 telli örgü tel	12.9	186	100
	15.2	232	139
	15.7	265	150
7 telli drawn örgü tel	12.7	209	112
	15.2	300	165
	18.0	380	223
Düşük Alaşımlı Çelik Çubuk			
1030/835	26.5	568	552
	32	830	804
	36	1048	1018
	40	1300	1257
1230/1080	25	600	491
	32	990	804
	36	1252	1018
Paslanmaz Çelik			
Tel	7	44.3	38.5
Çubuk	25	491	491
	32	804	804
	40	1257	1257

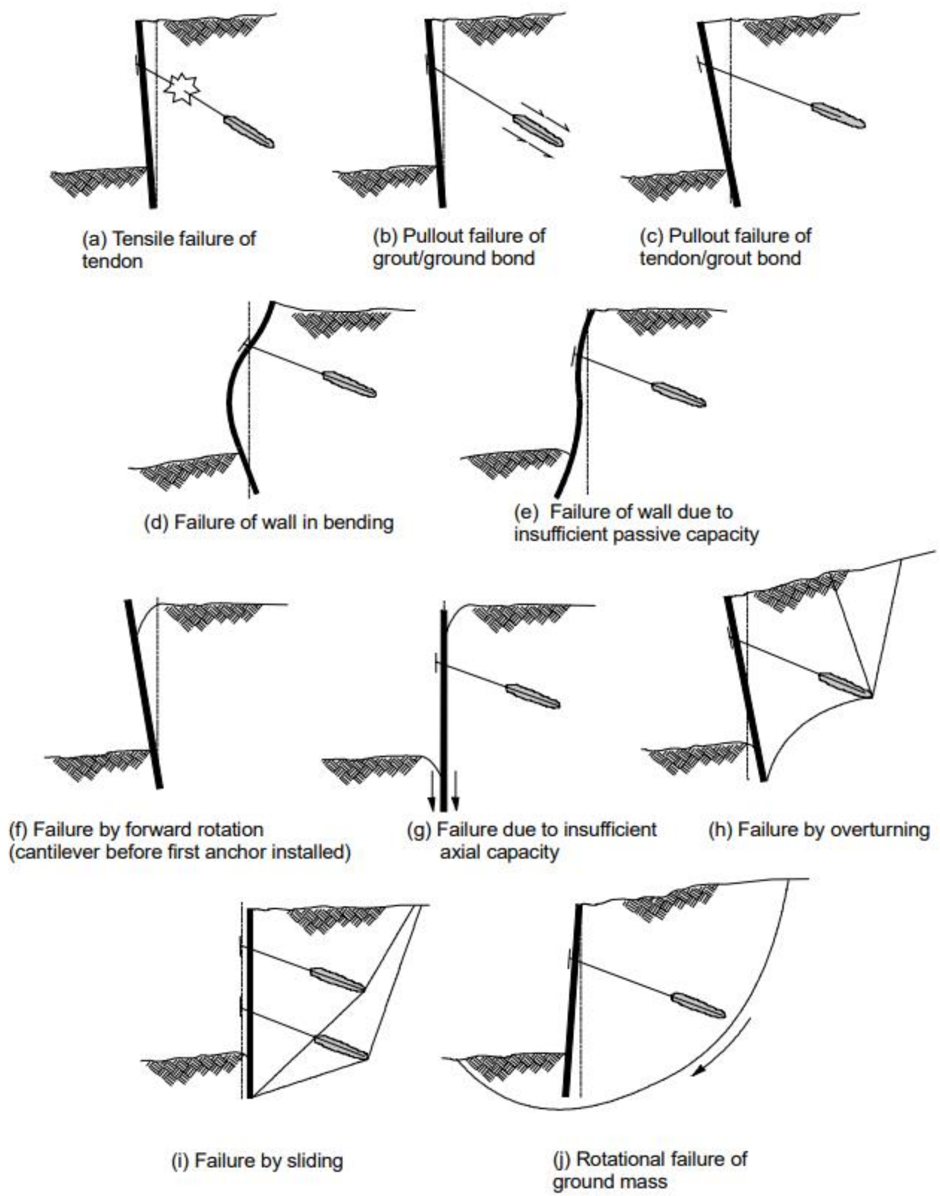
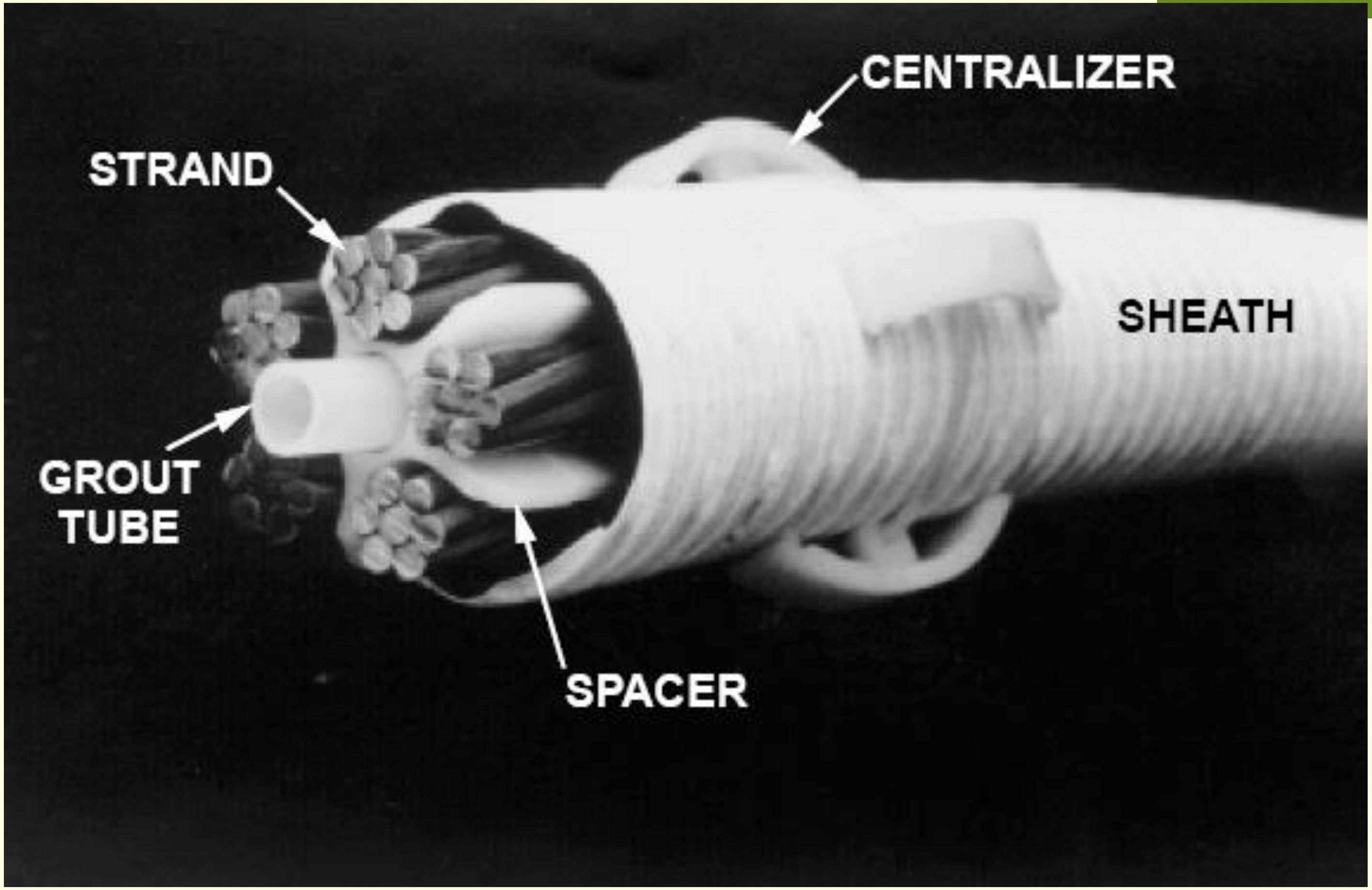


Figure 11. Potential failure conditions to be considered in design of anchored walls.

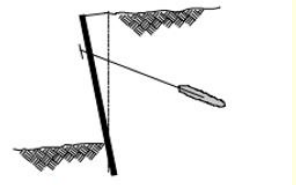
Strands



Internal Stability Analysis in Anchors

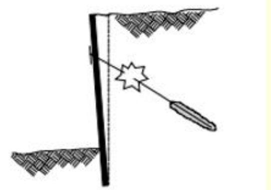
Internal stability of anchors is based on;

- **<u>1. Pullout failure of tendon/grout bond:</u>**



(c) Pullout failure of tendon/grout bond

- **<u>2-Tensile Failure of Tendon</u> :** If the prestress applied to anchor exceeds the tensile strength of steel tendons, the tendons will be broken and failure will take place. In design, the applied load must not exceed 0.6 times of strength of tendons in design and not exceed 0.8 times of strength in anchor loading tests.



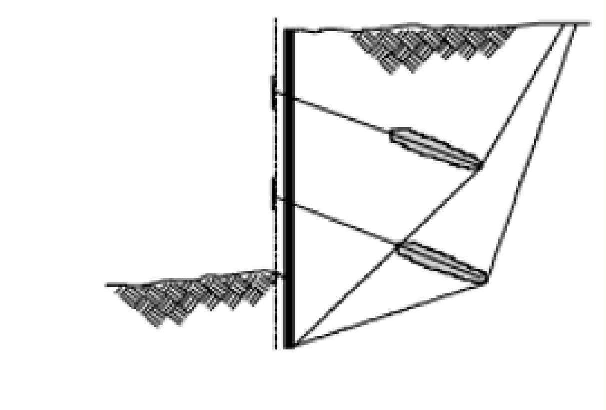
(a) Tensile failure of tendon

Zemin Ankrajlarında Stabilite Tahkikleri

- **<u>3- Pullout failure of grout/soil (ground) bond</u>**
- **<u>4-Deep Stability Check</u> :**

With the loads transmitted to the cnhor root, a block of soil surrounding the anchoor root may fail.

- In practice this problem is seen in shallow anchor roots and rarely encountered in deep anchor roots located at depths more than 5m.



1-Pullout Failure of Tendon/Grout Bond (Adherence Check Between Tendon/Grout)

- Safe bearing capacity of anchor tendons will be compared with the maximum anchor load ($P_{i,max}$).
- Number of tendons= ($P_{i\ max}$) / ($P_{pullout}$) (will be rounded to an integer).
  - $P_{pullout}$ = 232*0.6=139 kN
    - Not : In this project, tendon with 15.2mm diameter and 7 strands will be used. (Diameter=15.2mm, Cross sectional area =139 mm^2, Pullout capacity ($P_{pullout}$) = 232 kN)
- Safe bearing capacity of anchor tendons will be computed based on the number of tendons determined in the previous step.
- Determination of safe bearing capacity of Anchor tendons

$$P_{tendon,\ safe} = \tau_{em} \text{ x } A_{\text{tendon surface area}} \text{ x Number of tendons}$$

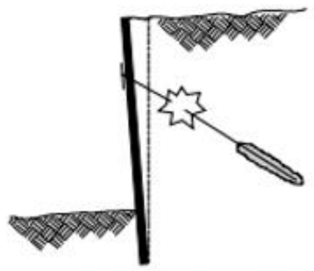
- ($A_{tendon} = \pi \text{ x } D_{tendon} \text{ x } L_{tendon}$)
- D_{tendon}= 15.2 mm= 0.0152 m
- For ribbed steel τ_{em}=700 kN/m^2

$$P_{tendon,\ safe} / P_{i\ max} > 2.0 \text{ (No adherence problem)}$$

2- Tensile Failure of Tendon

- $P_{pullout\ strength}$ / $P_{i,max}$ >1.4 (needs to be satisfied)

$P_{pullout\ strength}$ =232x0.6x number of tendons=139.2 kN x number of tendons=139.2

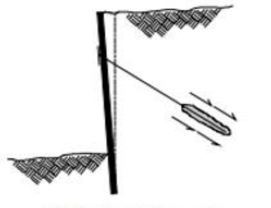


(a) Tensile failure of tendon

3- **Pullout failure of grout/soil (ground) bond**

- Capacity of Anchor root is computed .
  - $P_{anchor\ root}$ = Load capacity of Anchor root

$(P_{anchor\ root} = q_u \times A)$


(b) Pullout failure of grout/ground bond

  - A=Anchor root frictional area

    $(A=\pi x D x L)$ (Anchor root diameter (D) =15 cm)

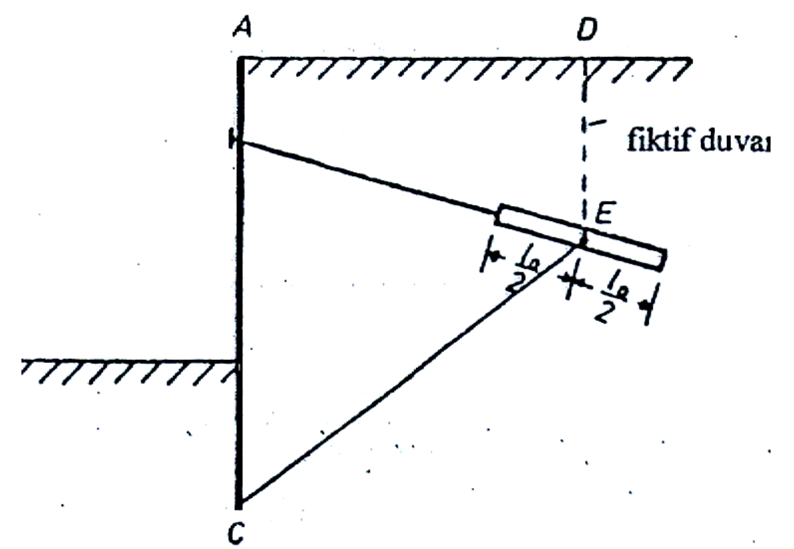
  - Ultimate unit bearing capacity (q_u) is computed by using the ultimate bearing capacity formula by considering the shear strength properties of the soil.

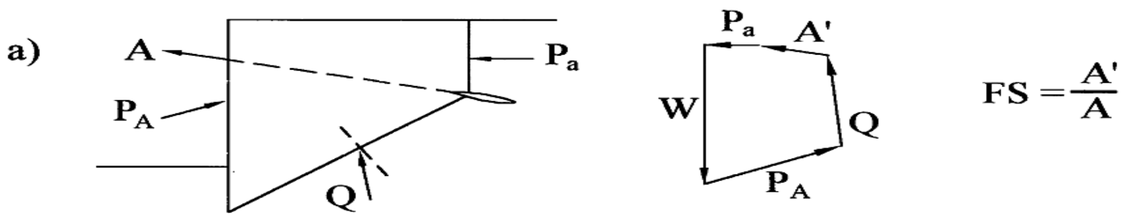
    $(q_u = c x N_c)$

  - Anchor root capacity ($P_{anchor\ root}$) is compared with the anchor capacity(P_i). FS needs to be greater than 2.0

Deep Stability Check

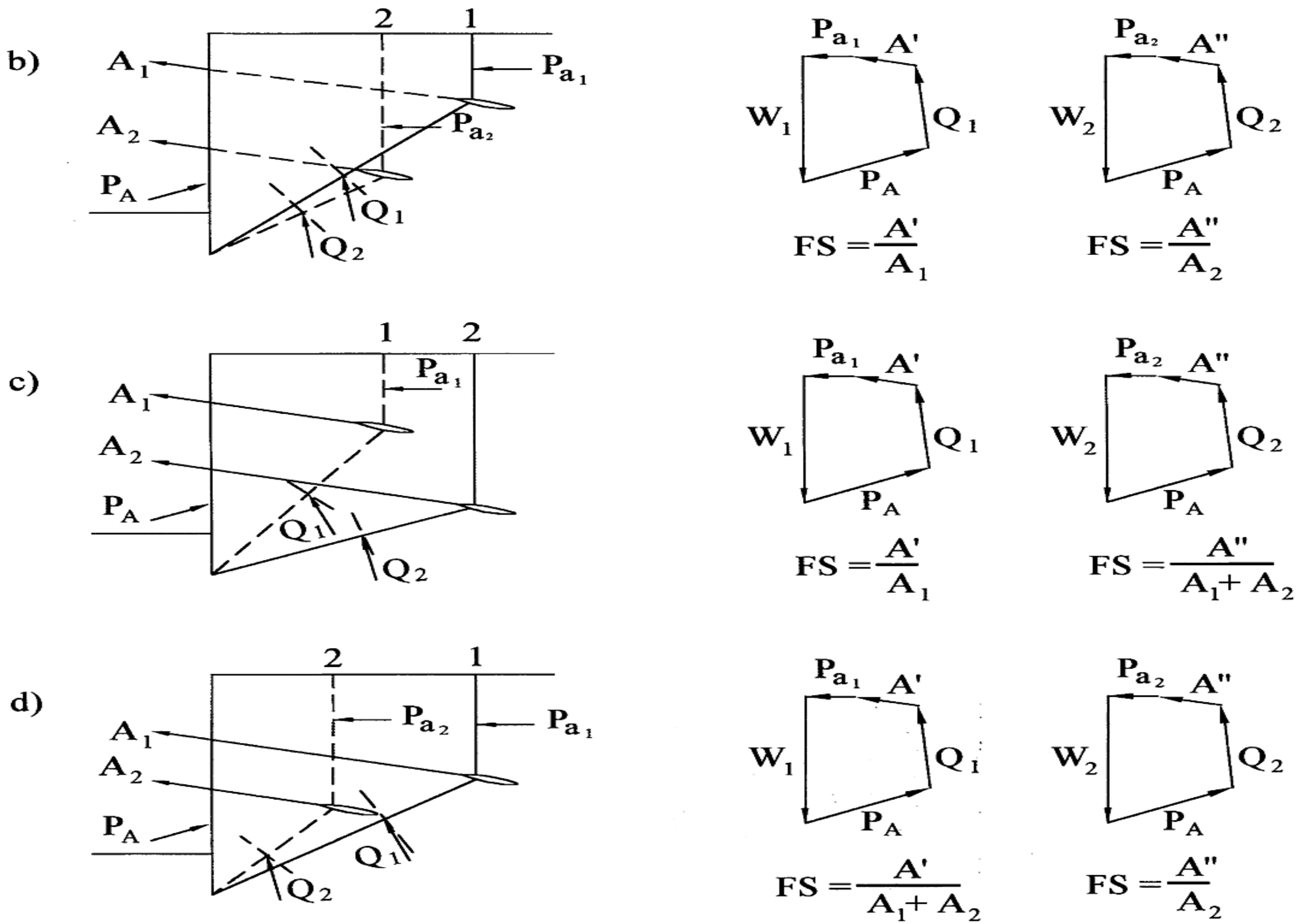
- For deep stability in anchored walls, a method based on Kranz is used.
    - A virtual plate is considered in the center of the anchor





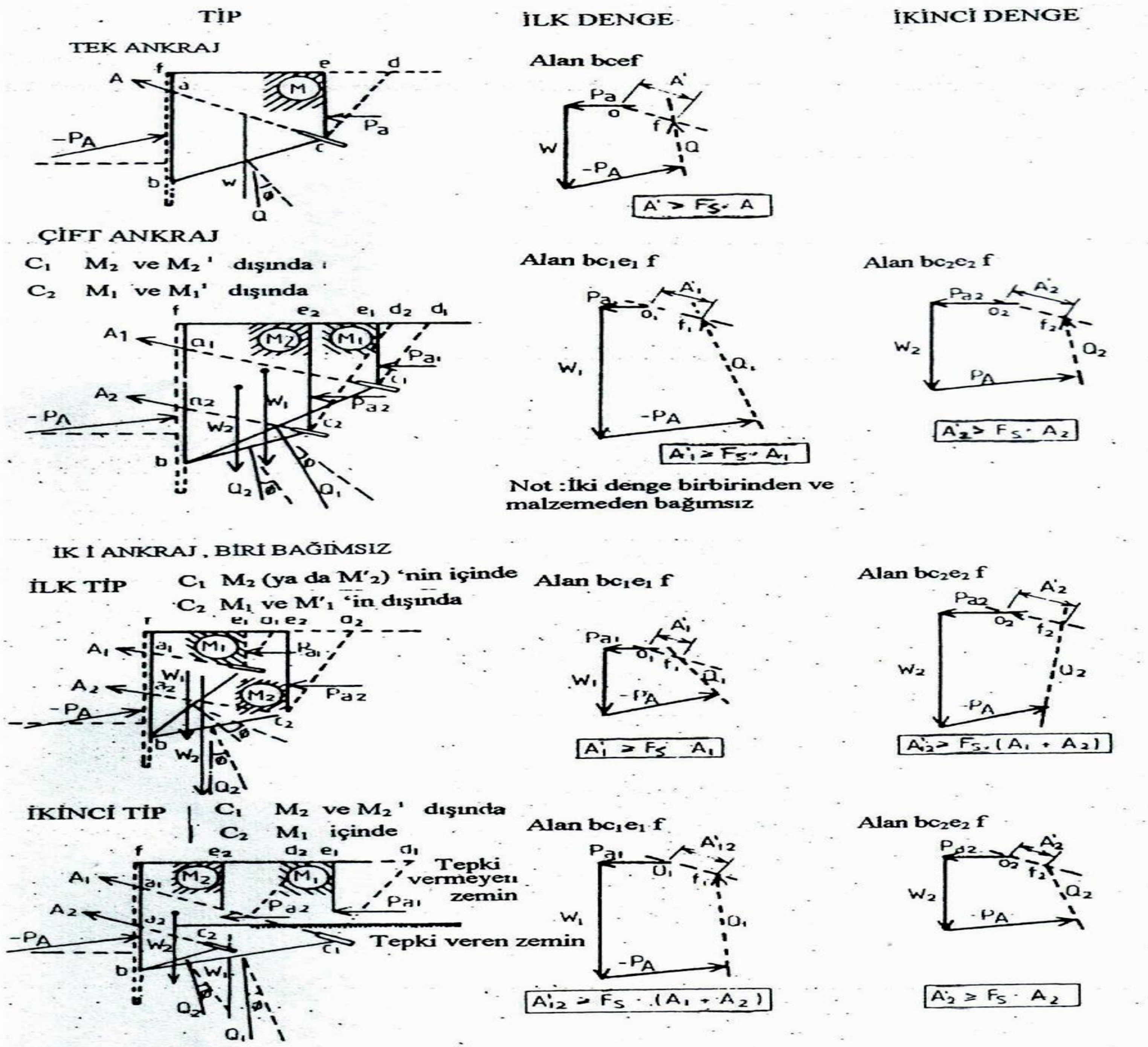
A' : Denge için uygulanabilecek maksimum kuvvet

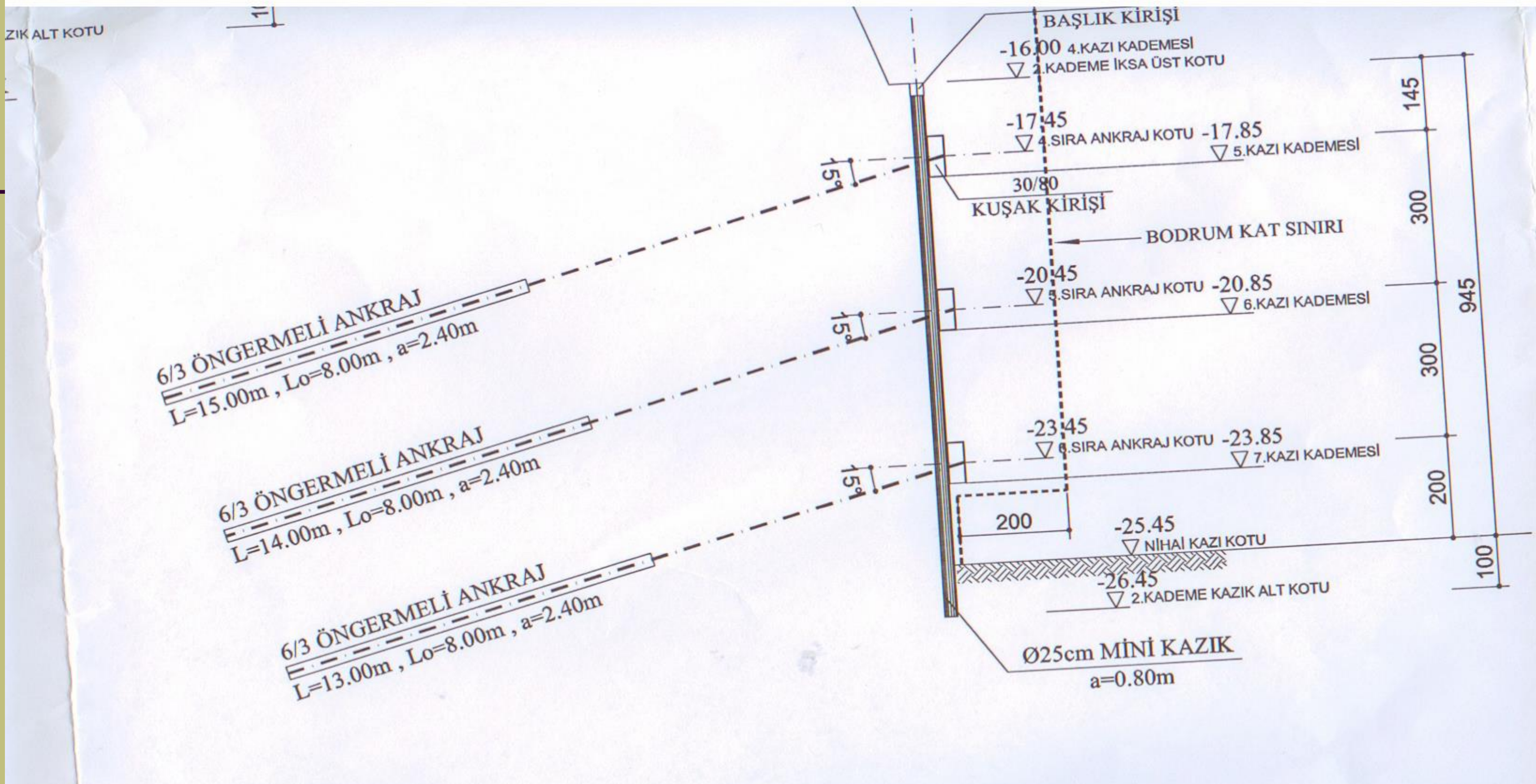
A : Ankraja uygulanan kuvvet



- Pa, Lateral earth pressure
- W, weight of block
- P_A, Resultant lateral earth pressure acting on the wall
- Q, bloc balancing force
- A,   Load acting on each anchor
- A′ equilibrium force

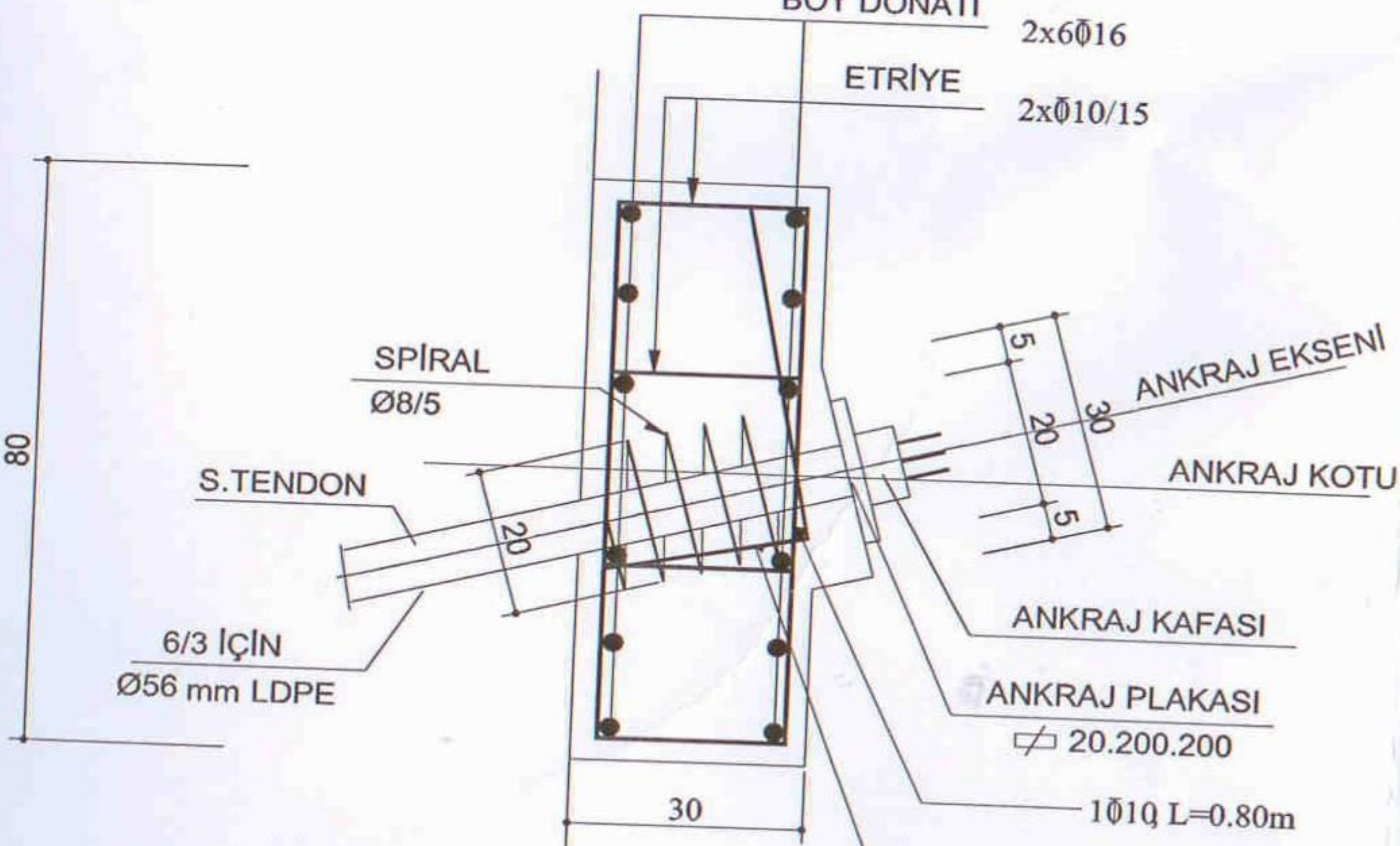
- Factor of safety FS=1.5-2.0


TİP
İLK DENGE
İKİNCİ DENGE
TEK ANKRAJ
Alan bcef
A' > Fs · A
ÇİFT ANKRAJ
C₁ M₂ ve M₂' dışında
C₂ M₁ ve M₁' dışında
Alan bc₁e₁ f
Alan bc₂e₂ f
A'₁ ≥ Fs · A₁
A'₂ > Fs · A₂
Not : İki denge birbirinden ve malzemeden bağımsız
İKİ ANKRAJ , BİRİ BAĞIMSIZ
İLK TİP
C₁ M₂ (ya da M'₂) 'nin içinde
C₂ M₁ ve M'₁ 'in dışında
Alan bc₁e₁ f
Alan bc₂e₂ f
A'₁ ≥ Fs A₁
A'₂ > Fs . (A₁ + A₂)
İKİNCİ TİP
C₁ M₂ ve M₂' dışında
C₂ M₁ içinde
Tepki vermeyen zemin
Tepki veren zemin
Alan bc₁e₁ f
Alan bc₂e₂ f
A'₁₂ ≥ Fs · (A₁ + A₂)
A'₂ ≥ Fs · A₂



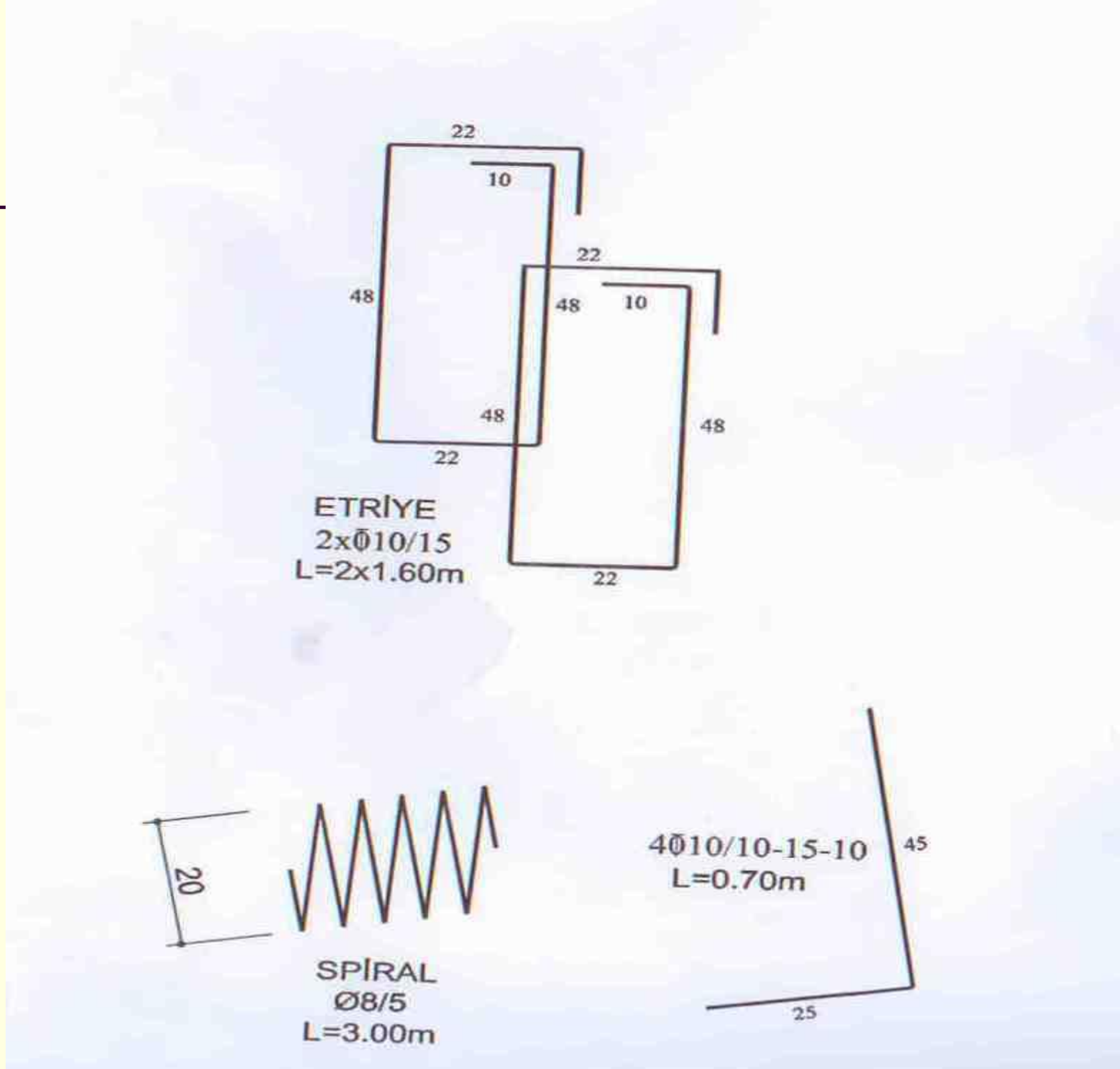
II-II İKSA KESİTİ

ÖLÇEK : 1/100



30/80 KUŞAK KİRİŞİ DETAYI

ÖLÇEK : 1/10


22
10
22
48
48
10
48
48
22
22
ETRİYE
2xΦ10/15
L=2x1.60m
20
SPİRAL
Ø8/5
L=3.00m
4Φ10/10-15-10
L=0.70m
45
25