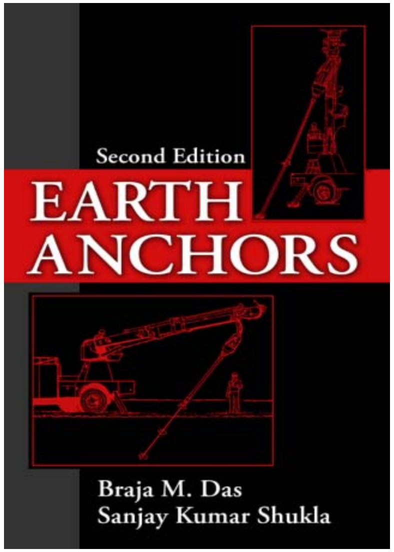
Chapter 1
Earth Anchors: General



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Earth anchors –purpose (Sec. 1.1)

- To resist outwardly directed loads on structures such as foundations, earth retaining structures, and slopes.
- The loads are transmitted to the soil and rock at greater depths.

Earth anchors – types (Sec. 1.1)

- Plate anchors
- Direct embedment anchors
- Helical anchors
- Grouted anchors
- Anchor piles and drilled shafts
- Suction caisson and drag anchors
- Geo-anchors

Plate anchors (Sec. 1.2)

- Plate anchors are made of steel plates, precast concrete slabs, timber sheets, etc.
- They may be horizontal, vertical and inclined.
- The horizontal plate anchor resists vertically directed uplifting load (see Fig. 1.2a).
- The inclined plate anchor resists axial pullout load (see Fig. 1.2a).
- The vertical plate anchor resists vertically directed uplifting load (see Fig. 1.2c).

Helical anchors (Sec. 1.4)

- Helical anchors consist of a steel shaft with one or more helices attached to it. (see Fig. 1.7).
- They can be of two types: single helix (screw) anchor, and multi-helix anchor.

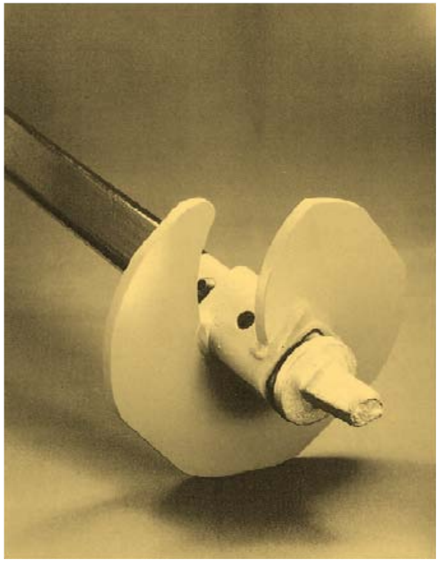


Fig. 1.8. Helical anchor with one helix

Helical anchors – some questions

?

- How are helical anchors installed?
- Can helical anchors resist tensile loads?
- Are helical anchors popular worldwide?

Think yourself and compare your answers with the details described in Sec. 1.4

Grouted anchors (Sec. 1.5)

- Grouted anchors consist of a steel bar or steel cable into a predrilled hole and then filling with cement grout.
- An application of grouted anchor is shown below:

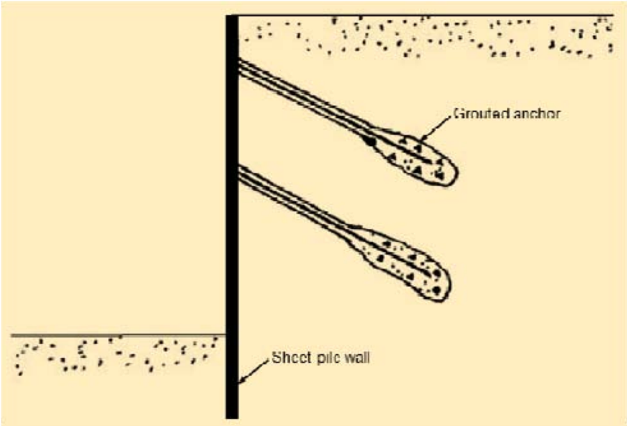


Fig. 1.13a. Sheet pile wall

See more applications in Fig. 1.13b and 1.13c.

Anchor piles and drilled shafts (Sec. 1.6)

- Anchor piles and drilled shafts are used in the construction of foundations.
- They serve dual purposes: support downward load, and resist uplift.

Suction caisson and drag anchors (Sec. 1.7)

- Suction caisson and drag anchors are used to secure mooring systems of buoyant platforms to the seabed.

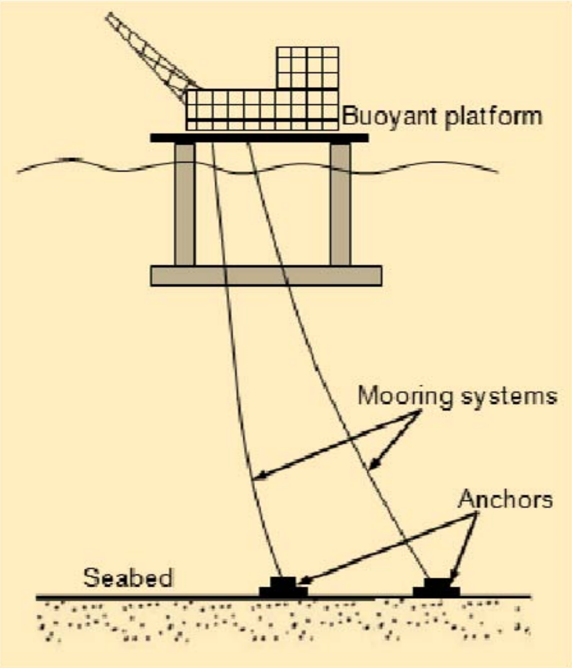


Fig. 1.15. Buoyant platform anchored to the sea bed.

Geo-anchors (Sec. 1.8)

- Geo-anchors can have several forms such as: geotextile-wrapped coarse-grained soil columns (Fig. 1.16), and trench anchors (Fig. 1.17).

?

Can you list some applications of geo-anchors?

Compare your list with those described in Sec. 1.8.

Summary of main points (Sec. 1.10)

- Earth anchors are primarily designed and constructed to resist outwardly-directed loads imposed on the structures.
- The plate anchors may be horizontal, inclined or vertical.
- Helical anchors consist of a steel shaft with one or more helices attached to it.

Get more main points in Sec. 1.10.

Summary of main points (Sec. 1.10)

- Earth anchors are primarily designed and constructed to resist outwardly-directed loads imposed on the structures.
- The plate anchors may be horizontal, vertical or inclined.
- Helical anchors consist of a steel shaft with one or more helices attached to it.

Get more main points in Sec. 1.10.

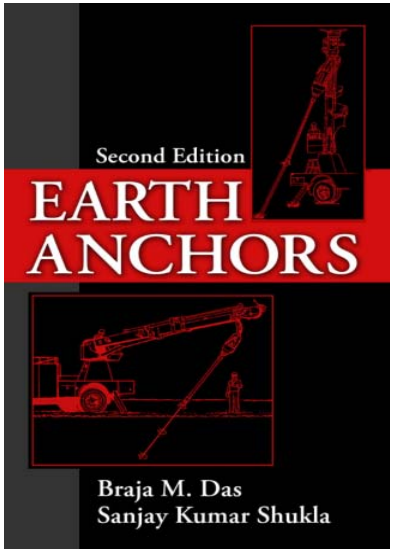
Self-assessment questions

1. The earliest form of anchor used in soil for resisting vertically-directed uplifting load is
(a) plate anchor.
(b) helical anchor.
(c) screw anchor.
(d) suction caisson anchor

2 The length-to-diameter ratio for suction caisson anchors is generally in the range of.
(a) 1 to 3.
(b) 3 to 6.
(c) 6 to 9.
(d) 9 to 12.

Get more questions and their answers on pages 15 and 16 of the book.

Chapter 2
Horizontal Plate Anchors in Sand



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Geometric parameters of a horizontal plate anchor (Sec. 2.1)

- Width = h
- Length = B ($\geq h$)
- Embedment depth = H
- Embedment ratio = H/h

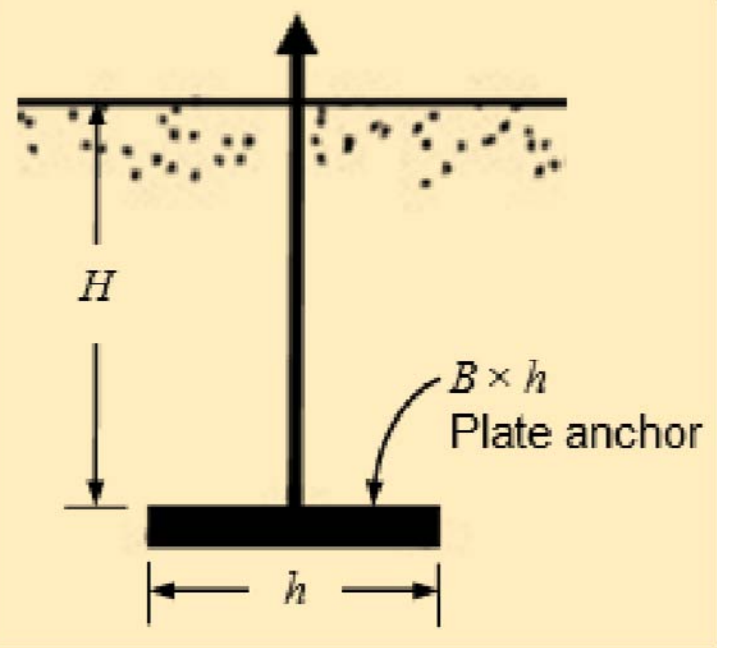


Fig. 2.1. A horizontal plate anchor

Anchor condition (Sec. 2.1)

- Shallow anchor condition: The failure surface intersects the horizontal ground.
- Deep anchor condition: The failure surface does not extend to the ground surface.

Uplift capacity (Sec. 2.1)

- $Q_{u(g)}$ = gross ultimate uplift capacity
- Q_u = net ultimate uplift capacity
- W_a = effective self-weight of the anchor

$$Q_{u(g)} = Q_u + W_a$$

Equation 2.1

Net ultimate uplift capacity Q_u versus embedment ratio *H/h*

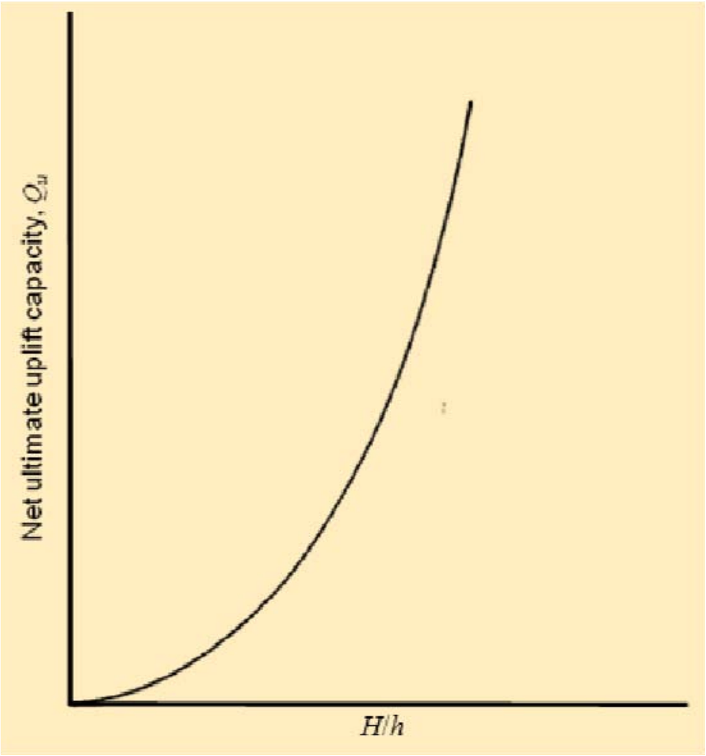


Fig. 2.8

Anchor theories - list

- Early theories
  - Soil cone method (Sec. 2.2.1)
  - Friction cylinder method (Se. 2.2.2)
- Balla’s theory (Sec. 2.3)
- Baker and Konder’s empirical relationship (Sec. 2.4)
- Mariupoli’skii’s theory (Sec. 2.5)
- Mayerhof and Adams’s theory (Sec. 2.6)
- Veesaert and Clemence’s theory (Sec. 2.7)
- Vesic’s theory (Sec. 2.8)
- Saeedy’s theory (Sec. 2.9)

?

Can you describe the mathematical derivations involved in these theories? (The derivations are well-explained in Chapter 2.)

Breakout factor (F_q)

$$F_q = \frac{Q_u}{\gamma A H}$$

Equation 2.10

- A = area of the plate
- γ = unit weight of soil
- H = embedment depth
- Q_u = net ultimate uplift capacity

The breakout factor helps decide the type of anchor condition.

Breakout factor F_q versus embedment ratio *H/h*

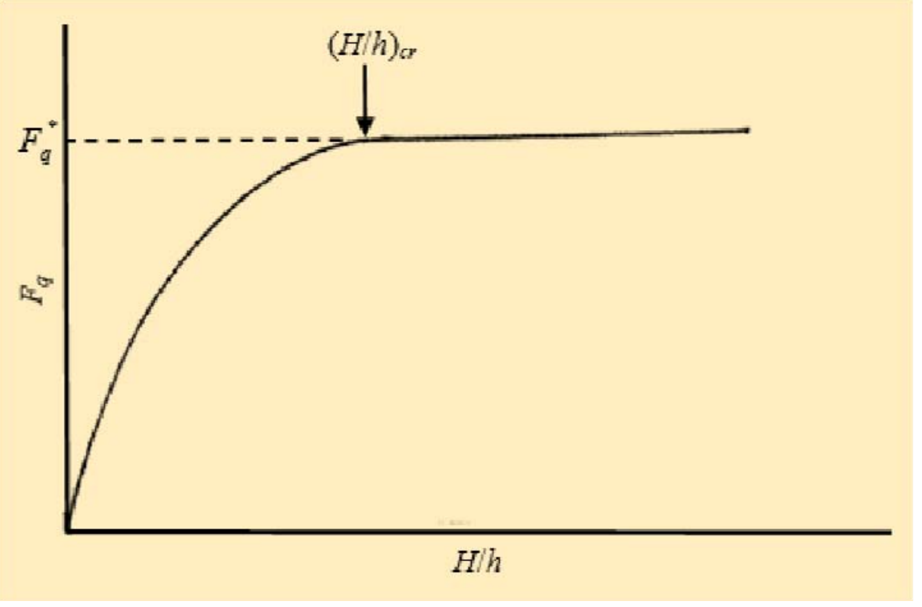


Fig. 2.9

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on page 27.)

Discussion of various theories (Sec. 2.10)

- All of the theories, except that of Meyerhof and Adams (1968), are for axisymmetric case (that is, for use in the case of circular anchors). Meyerhof and Adams' theory addresses the case of rectangular anchors.
- Most theories assume that the shallow anchor condition exists for $H/B \leq 5$. Meyerhof and Adams' theory provides a critical embedment ratio $(H/h)_{cr}$ for square and circular anchors as a function of the soil friction angle.
- Vesic's theory (1971) is generally fairly accurate in estimating the net ultimate uplift capacity for shallow anchors in loose sand. However, for shallow anchors embedded in dense sand, this theory can underestimate the actual capacity by as much as 100% or more.

Allowable net ultimate uplift capacity (sec. 2.11)

- Use a tentative factor of safety F_s
- Use a load-displacement relationship

$$Q_{u(all)} = \frac{Q_u}{F_s}$$

Equation 2.52

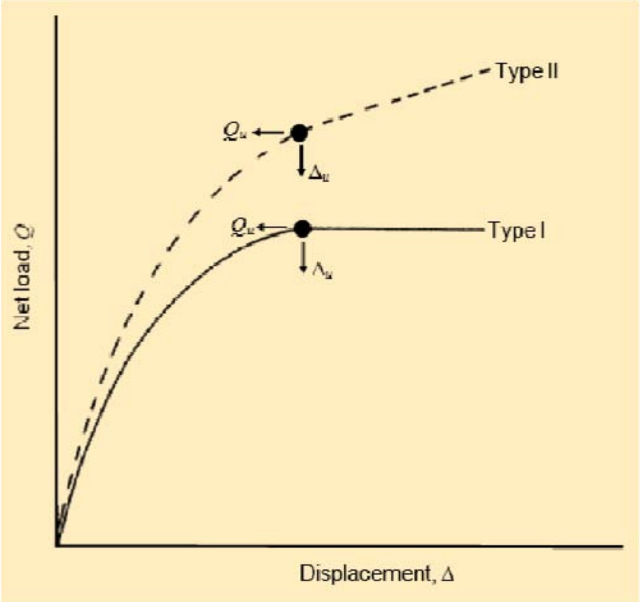


Fig. 2.30

Some other key topics

- Anchors subjected to repeated loading (Sec. 2.12)
- Uplift capacity of shallow group anchors (Sec. 2.13)
- Spread foundations under uplift (Sec. 2.14)

Inclined load resistance (Sec. 2.15)

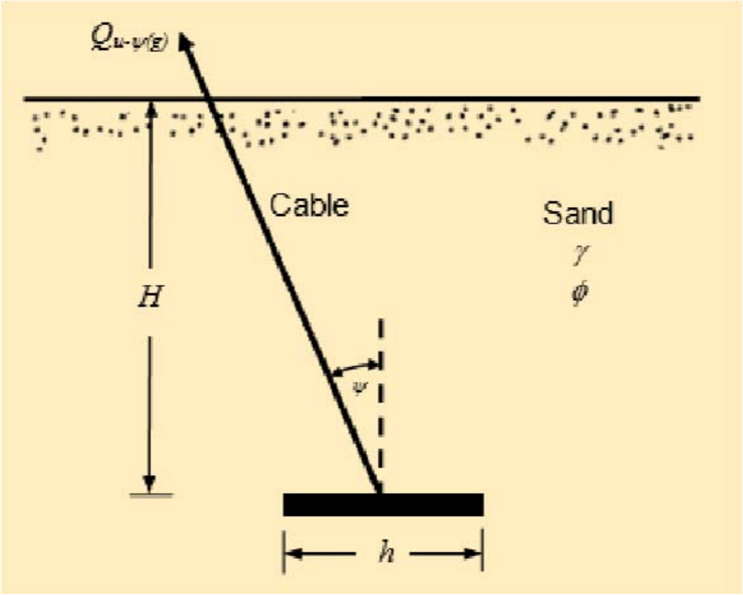


Fig. 2.42

$$Q_{u-\psi} = Q_{u-\psi(g)} - W_a \cos\psi$$

Equation 2.52

Other studies (Sec. 2.16)

- Merifield and Sloan (2006)
- Merifield et al. (2006)
- Kumar and Kouzer (2008b)
- White et al. (2008)
- Deshmukh et al. (2011)
- Kumar (2011)

?

Can you list the major findings of recent developments?
(Compare your list with those described in Sec. 2.16)

Example 2.1

- Consider a circular anchor plate embedded in sand. Given, for the anchor: diameter, h = 0.3 m; depth of embedment, H = 1.2 m. Given, for the sand: unit weight, γ= 17.4 kN/m^3; friction angle, ϕ = 35°. Using Balla's theory, calculate the net ultimate uplift capacity.

Answer: **21.8 kN**
(Find the complete solution on page 55.)

Example 2.5

- Consider a shallow rectangular anchor embedded in sand for which the following are given: h = 0.3 m, B = 0.9 m, H = 1.2 m. For the sand, given: γ = 18 kN/m^3, ϕ = 35°. Estimate:
- the net ultimate uplift capacity using the theory of Meyerhof and Adams (1968),
- the anchor displacement at ultimate load, and
- the net load Q at an anchor displacement of $0.5\Delta_u$

Answer: **36.86 kN**, **180 mm**, **31.37 kN**
(Find the complete solution on pages 60-61.)

Summary of main points (Sec. 2.17)

- Horizontal plate anchors are used in the construction of foundations subjected to uplifting load.
- The embedment ratio of the anchor is the ratio of the depth of embedment (H) to the width of the anchor (h), that is, H/h, which governs the anchor condition as shallow and deep. For greater values of H/h, deep condition occurs where the failure surface does not extend to the ground surface.

Get more main points in Sec. 2.17.

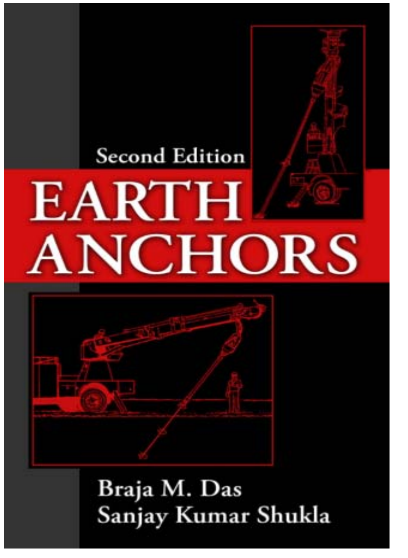
Self-assessment questions

1. The breakout factor:
 (a) always increases with increase in embedment ratio
 (b) increases with increase in embedment ratio up to a maximum value
 (c) always decreases with increase in embedment ratio
 (d) decreases with increase in embedment ratio up to a minimum value

2 Horizontal plate anchors for transmission line towers are usually constructed with an embedment ratio of:
 (a) 3
 (b) 3 or less
 (c) greater than 3
 (d) 1

Get more questions and their answers on pages 77-78 of the book.

Chapter 3
Horizontal Plate Anchors in Clay



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Geometric parameters of a horizontal plate anchor (Sec. 3.1)

- Width = h
- Length = B ($\geq h$)
- Embedment depth = H
- Embedment ratio = H/h

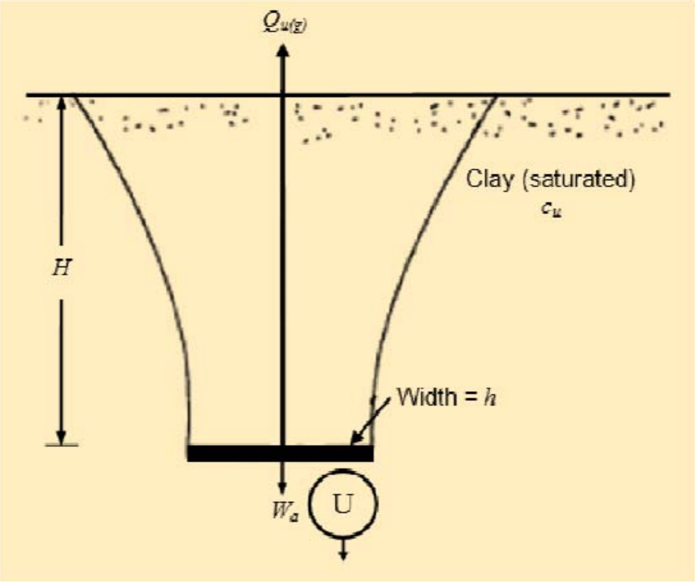


Fig. 3.1. A horizontal plate anchor in clay

Suction force (Sec. 3.1)

- When the anchor is subjected to an uplift force, a suction force *U* is induced below the anchor.

Can you explain the reason?
(Compare your answer with the explanation given on page 81.)

Uplift capacity (Sec. 3.1)

- $Q_{u(g)}$ = gross ultimate uplift capacity
- Q_u = net ultimate uplift capacity
- W_a = effective self-weight of the anchor
- U = suction force below the anchor

$$Q_{u(g)} = Q_u + W_a + U$$

Equation 3.1

Anchor theories - list

- Vesic's theory (Sec. 3.2)
- Meyerhof's theory (Sec. 3.3)
- Das's theory (Sec. 3.4)
- Three-dimensional lower bound solution (Sec. 3.5)

Can you describe the mathematical derivations/details involved in these theories? (The derivations are well-explained in Chapter 3.)

Breakout factor F_c versus embedment ratio *H/h*

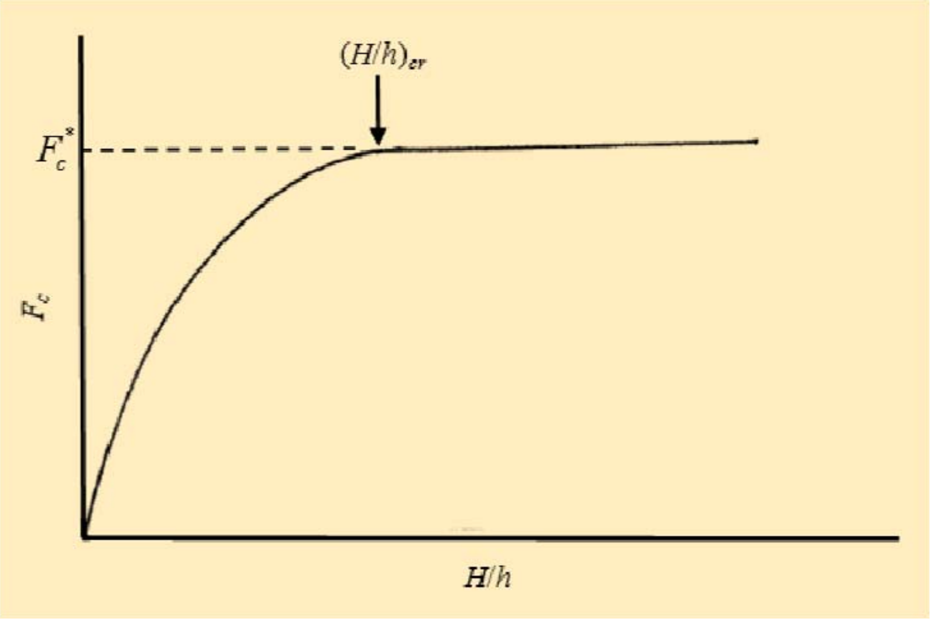


Fig. 3.3

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on page 83.)

Factor of safety (Sec. 3.6)

- In most cases of anchor design, a factor of safety of 2 to 2.5 is used to arrive at the net ultimate uplift capacity.

Uplift capacity of anchors in layered soil (Sec. 3.7)

- The sand overlay can significantly increase the net ultimate uplift capacity.

- The net ultimate uplift capacity is composed of two parts as:

$$Q_u = Q_{u(clay)} + Q_{u(sand)}$$

Other studies (Sec. 3.8)

- Rowe and Davis (1982)
- Merifield et al. (2001)
- Song et al. (2008)

?

Can you list the major findings of recent developments?
(Compare your list with those described in Sec. 3.8)

Example 3.1

- A plate anchor that measures 0.4 m × 0.6 m is embedded at a depth of 1.8 m. The undrained cohesion of the clay is 42 kN/m^2, and its saturated unit weight γ is 18.9 kN/m^3. Estimate the net ultimate uplift capacity.

Answer: **78.6 kN**
(Find the complete solution on pages 92-93.)

Example 3.2

- A square horizontal plate anchor 0.25 m wide is to be embedded 1.75 m in a homogeneous clay. Determine the ultimate pullout capacity given that the clay has a shear strength c_u = 60 kPa and unit weight γ = 15.3 kN/m^3.

Answer: **44.6 kN**
(Find the complete solution on pages 95-96.)

Summary of main points (Sec. 3.9)

- Vesic's theory gives a closer estimate of the uplift capacity only for shallow horizontal plate anchors embedded in softer clays.
- The lower bound limit analysis and small strain finite element analysis may overestimate the pullout capacity of horizontal plate anchors during vertical pullout.

Get more main points in Sec. 3.9.

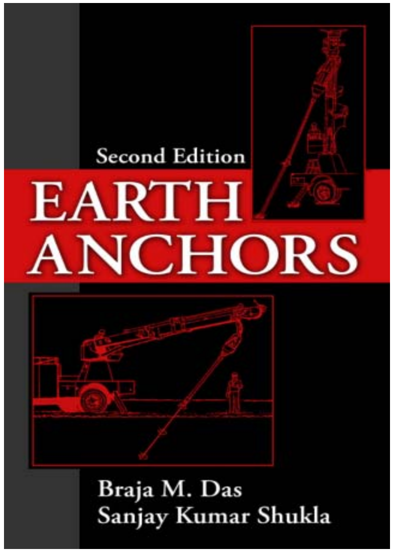
Self-assessment questions

1. Das's theory is applicable to:
 (a) circular anchors only
 (b) square anchors only
 (c) rectangular anchors only
 (d) circular, square and rectangular anchors

2 According to three-dimensional lower bound solution, the limiting value of the breakout factor for circular anchors is approximately:
 (a) 0
 (b) 11.9
 (c) 12.56
 (d) none of the above

Get more questions and their answers on pages 102-103 of the book.

Chapter 4
Vertical Plate Anchors



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Geometric parameters of a vertical plate anchor (Sec. 4.1)

- Height = *h*
- Width = *B*
- Embedment depth = *H*
- Embedment ratio = *H*/*h*
- Width to height ratio = *B*/*h*

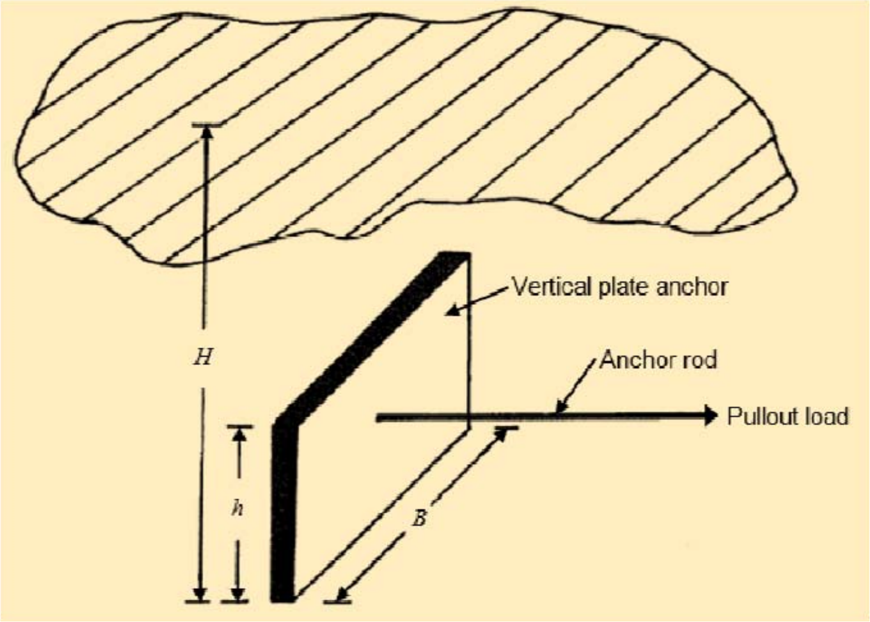


Fig. 4.2.

Use of vertical plate anchors (Sec. 4.1)

- To resist the horizontal loading in the construction of sheet pile walls.

?

Can you list some more applications?
(Compare your answer with applications mentioned on page 106.)

Holding capacity (Sec. 4.1)

The ultimate holding capacity Q_u is a function of the following:

- H/h
- B/h
- Shear strength parameters (c, ϕ)
- Angle of friction of the anchor-soil interface, δ

The holding capacity of the anchor is primarily derived from the passive force imposed by the soil in front of the anchor slab.

Anchors in sand – list of theories

- Rankine's theory (Sec. 4.2.1)
- Analysis of Ovesen and Stromann (Sec. 4.2.2)
- Analysis of Meyerhof (Sec. 4.2.3)
- Analysis of Biarez et al. (Sec. 4.2.4)
- Analysis of Neely et al. (Sec. 4.2.5)

Can you describe the mathematical derivations/details involved in these theories? (The derivations are well-explained in Chapter 4.)

Anchors in sand – Nature of passive pressure distribution

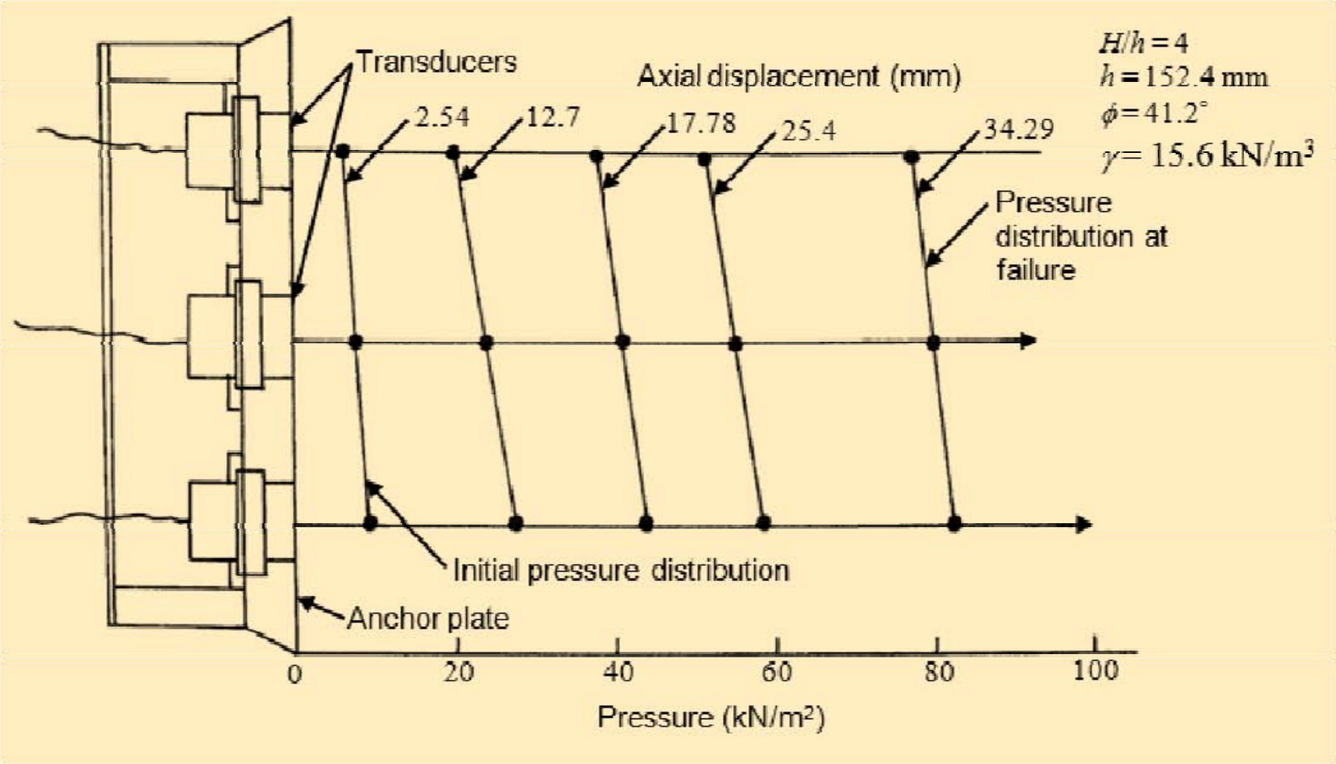


Fig. 4.2.

Anchors in sand: Breakout factor F_q versus embedment ratio *H/h* (Sec. 4.2.7)

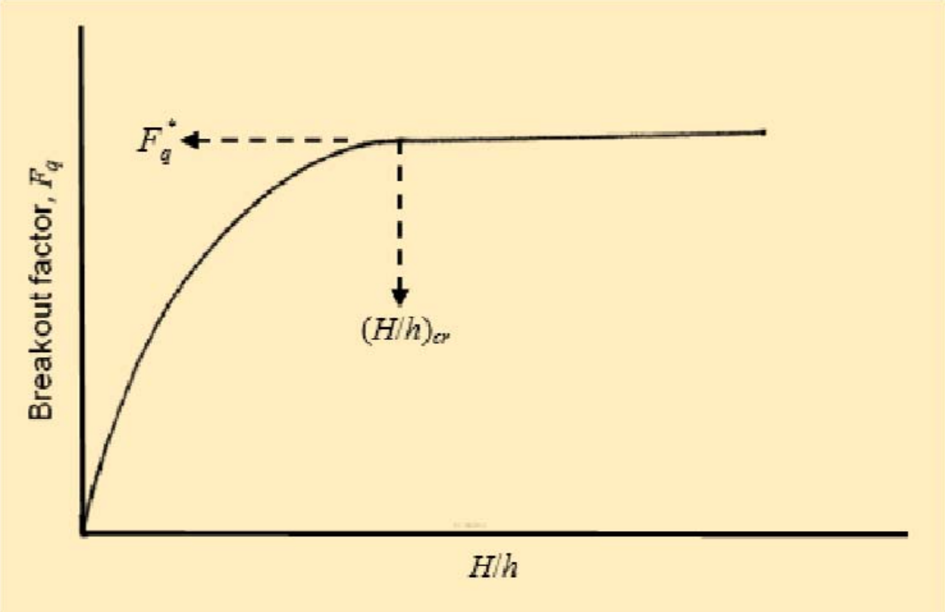


Fig. 4.25

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on pages 134-135.)

Anchors in sand – design considerations (Sec. 4.2.9)

- Prediction of holding capacity of anchors for design requires careful consideration of the soil friction angle.
- For routine works, plane strain tests on sand are rarely conducted in the laboratory to determine the friction angle. Therefore, it is recommended that the triaxial peak friction angle at a confining pressure of about 10 psi (100 kN/m^2) be determined. The $\phi_{peak\ (triaxial)}$ will be about 10% less than the magnitude of $\phi_{peak\ (plane\ strain)}$.

Get more guidelines in Sec. 4.2.9.

Anchors in clay (Undrained cohesion, ϕ - 0)(Sec. 4.3) – Geometric parameters

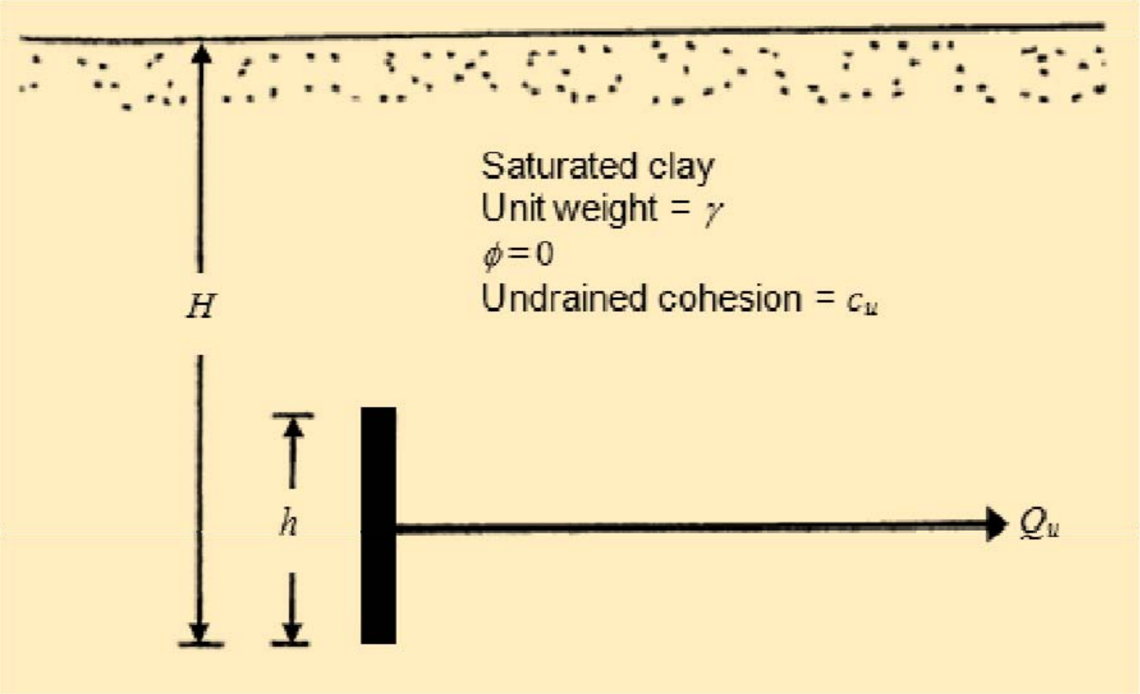


Fig. 4.40

Anchors in clay: Breakout factor F_c versus embedment ratio *H/h (Sec. 4.3)*

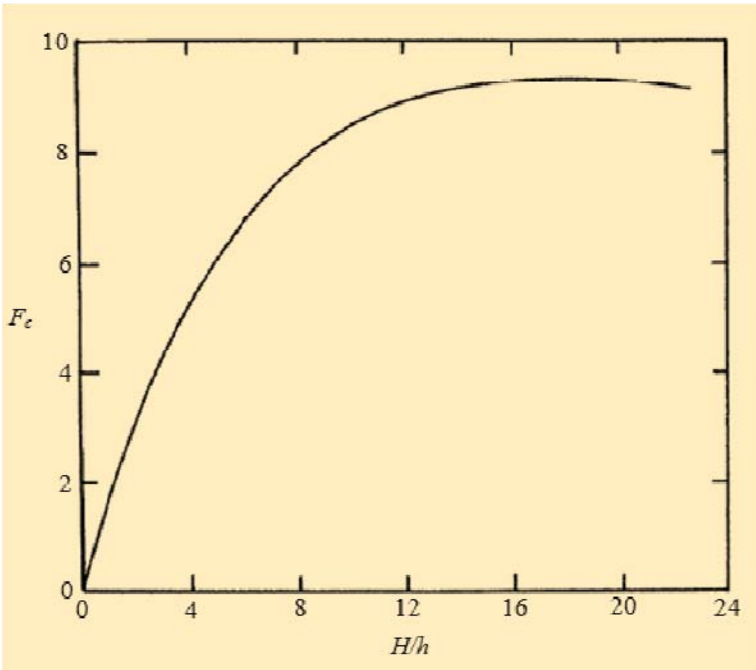


Fig. 4.41

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on page 152.)

Other studies (Sec. 4.4)

- Rowe and Davis (1982)
- Ghaly (1997)
- Merifield (2001)

?

Can you list the major findings of recent developments?
(Compare your list with those described in Sec. 4.4)

Example 4.1

- For a vertical plate anchor, assume the following values: h = 2 ft, B = 5 ft, H = 4 ft, γ = 105 lb/ft^3 and ϕ = 32°. Determine the ultimate holding capacity, Q_u.

Answer: **13,060 lb**
(Find the complete solution on pages 111-112.)

Example 4.6

- Estimate the ultimate breakout load of a rectangular anchor plate with the following: H = 1.2 m, h = 0.3 m, B = 0.6 m, and c_u = 48 kN/m^2.

Answer: **51.43 kN**
(Find the complete solution on pages 158-159.)

Summary of main points (Sec. 4.9)

- For vertical anchors, the gross ultimate holding capacity is equal to the net ultimate holding capacity.
- The critical embedment ratio in soft and medium clays increases with undrained shear strength up to a maximum limit and remains constant thereafter.

Get more main points in Sec. 4.5.

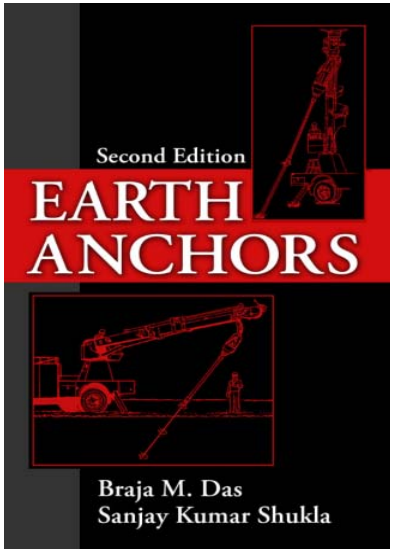
Self-assessment questions

1. The dividing line between the shallow and deep anchors of failure is:
 (a) critical embedment ratio
 (b) width of the anchor and height of the anchor plate
 (c) depth of the anchor plate
 (d) soil type

2 The breakout factor for deep square anchors is:
 (a) 1
 (b) 3
 (c) 5
 (d) 9

Get more questions and their answers on pages 162-164 of the book.

Chapter 5
Inclined Plate Anchors



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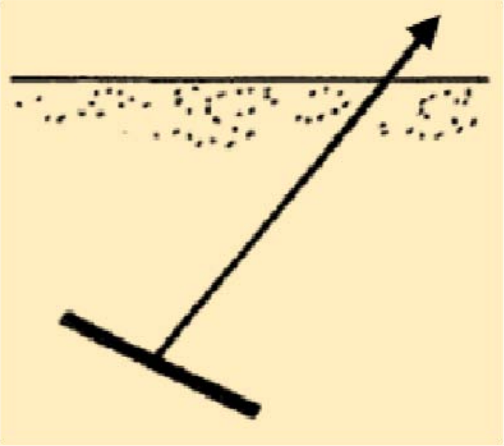
Inclined Plate Anchors (Sec. 5.1)

- Plate anchors are sometimes placed at an inclination to the horizontal with inclined or axial pull



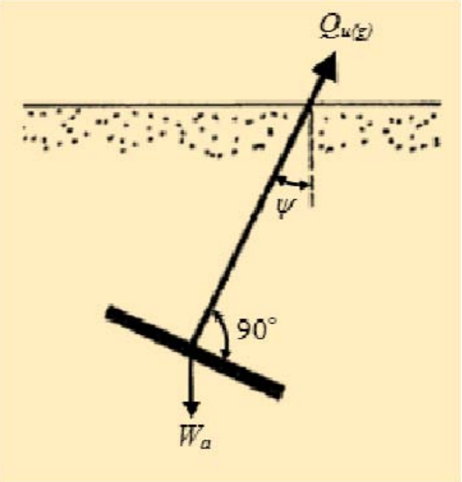


Fig. 5.1

Holding capacity (Sec. 5.1)

The gross ultimate holding capacity is given as:

$$Q_{u(g)} = Q_u + W_a \cos\psi \qquad \textbf{Eq. (5.1)}$$

Inclined plate anchors in sand – list of theories

- Analysis of Harvey and Burley (Sec. 5.2.1)
- Meyerhof's procedure (Sec. 5.2.2)
- Analysis of Hanna et al. (Sec. 5.2.3)
- Empirical relationships (Sec. 5.2.4)

?

Can you describe the mathematical derivations/details involved in these theories? (The derivations are well-explained in Chapter 5.)

Inclined plate anchors in sand: Breakout factor F_q versus embedment ratio H'/h (Sec. 5.2.2)

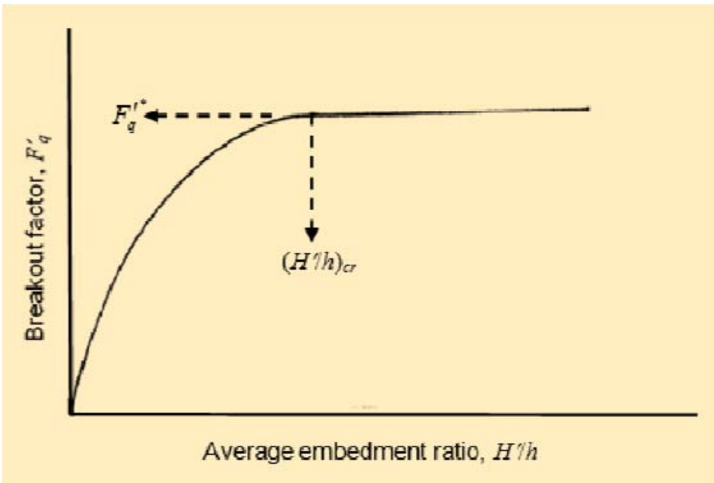


Fig. 5.5

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on page 175.)

Inclined plate anchors in sand – General remarks (Sec. 5.2.5)

- The present theories on inclined anchors are primarily based on observations made during model tests in the laboratory. Further full-scale tests are essential to verify the assumptions and results.
- Due to the uncertainties involved, a factor of safety of at least 3 may be used to obtain the allowable holding capacity.

Get more guidelines in Sec. 5.2.5.

Inclined plate anchors in clay (Undrained cohesion, ϕ - 0)(Sec. 5.3)

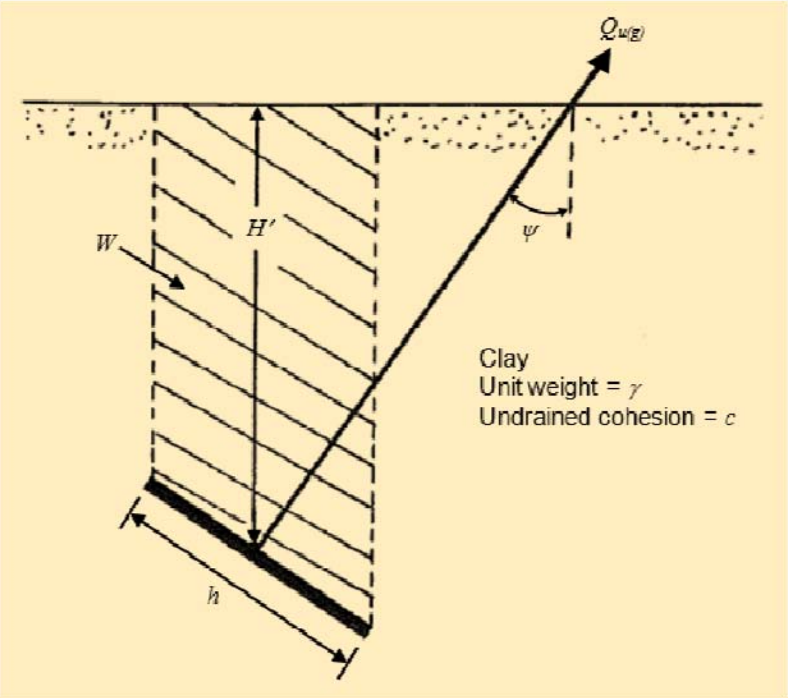


Fig. 5.19

Anchors in clay: Breakout factor versus embedment ratio *H/h* (Sec. 5.3)

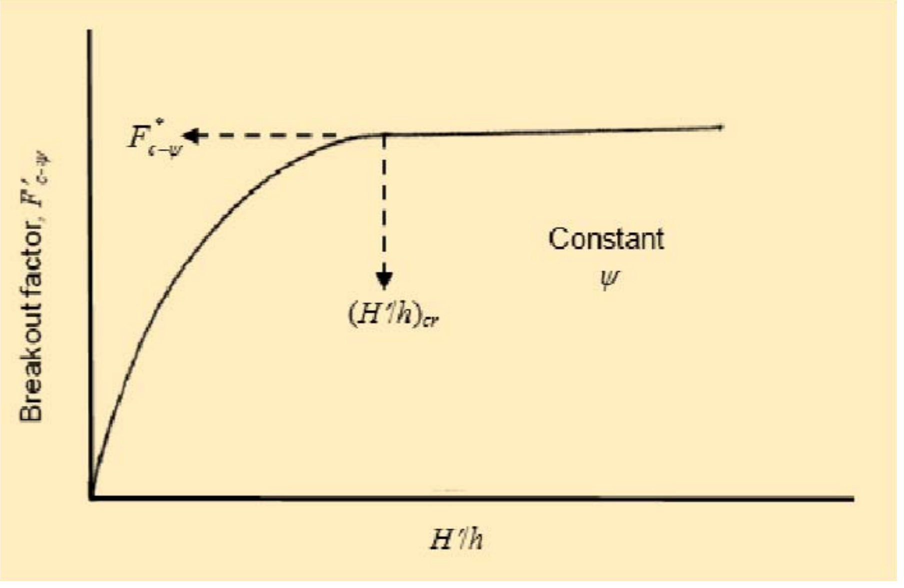


Fig. 5.20

?

Can you explain the importance of this plot? (Compare your answer with the explanation given on page 198.)

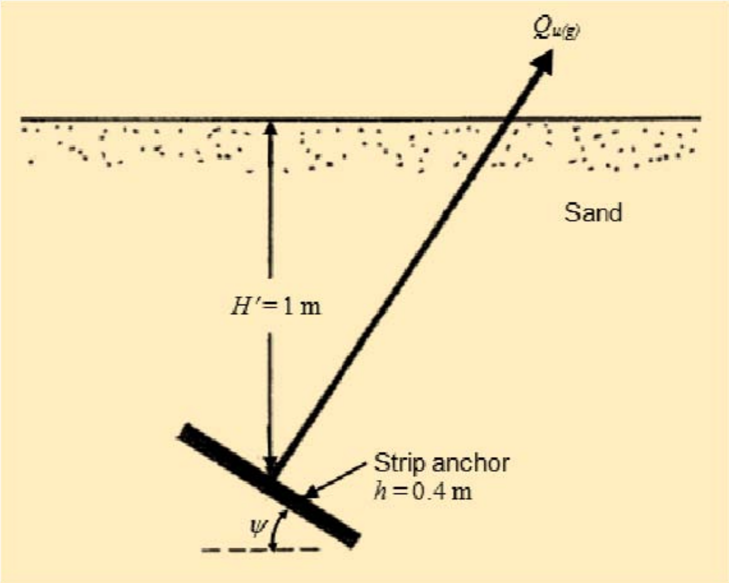
Other studies (Sec. 5.4)

- Merifield et al. (2005)

Can you list the major findings of recent developments?
(Compare your list with those described in Sec. 5.4)

Example 5.1

- For the strip anchor shown in Figure 5.8, ϕ = 35°, γ = 17 kN/m^3, h = 0.4 m, H' = 1 m. Determine the variation of the net ultimate load for ψ = 20°, 45°, 75° and 90°.



Answer: **19.99 kN/m, 23.81 kN/m, 33.21 kN/m, 47.74 kN/m**
(Find the complete solution on pages 178-180.)

Example 5.5

- Consider an anchor embedded in a saturated clay. For the anchor: h = 0.4 m; H' = 1.2; B = 0.8 m; ψ = 30°. Given, for the clay: c_u = 28 kN/m^2; γ = 18.4 kN/m^3. Calculate the net ultimate holding capacity.

Answer: **56.55 kN**
(Find the complete solution on pages 201-204.)

Summary of main points (Sec. 5.5)

- The theory of Hanna et al. (1988) provides excessively high values of the ultimate anchor capacity.
- The anchor displacement along the direction of pull at ultimate load gradually increases with the anchor inclination.

Get more main points in Sec. 5.5.

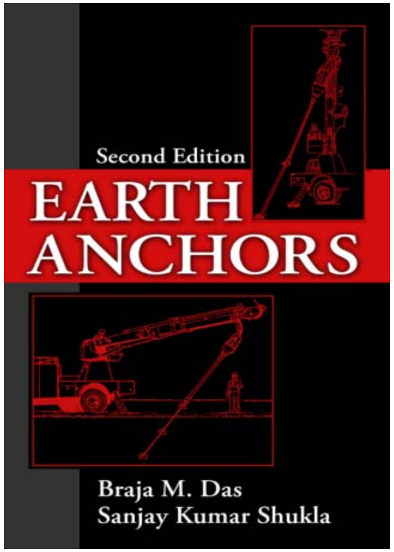
Self-assessment questions

1. The present theories on inclined anchors are primarily based on observations made during:
(a) small-scale tests in the laboratory
(b) large-scale tests in the laboratory
(c) large-scale tests in the field
(d) field conditions

2 For a shallow inclined anchor, with increase in overburden pressure, the ultimate anchor capacity:
(a) does not vary
(b) varies linearly
(c) decreases linearly
(d) increases linearly

Get more questions and their answers on pages 205-206 of the book.

Chapter 6
Helical Anchors in Sand



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Typical multi-helix anchor used in the United States (Sec. 6.1)

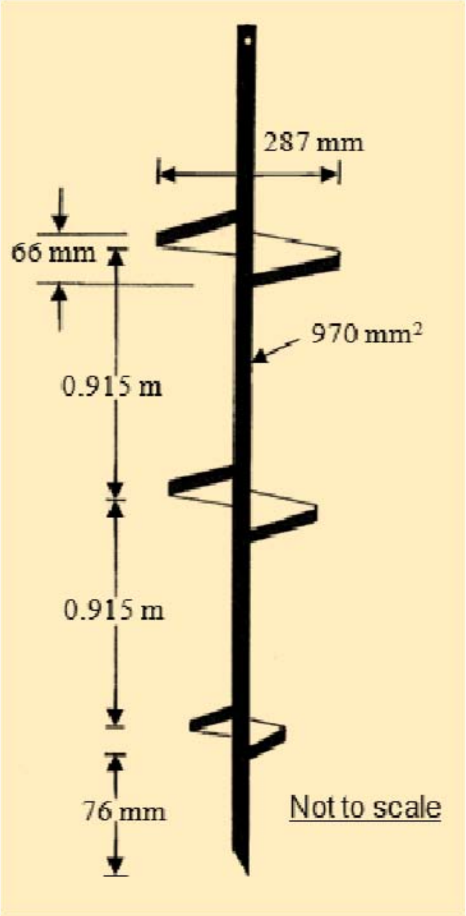


Fig. 6.1.

Single helix (Screw) anchor – types (Sec. 6.2)

- Shallow screw anchor
- Deep screw anchor
- Transit screw anchor

Shallow screw anchor – assumed and observed failure surfaces (Sec. 6.2)

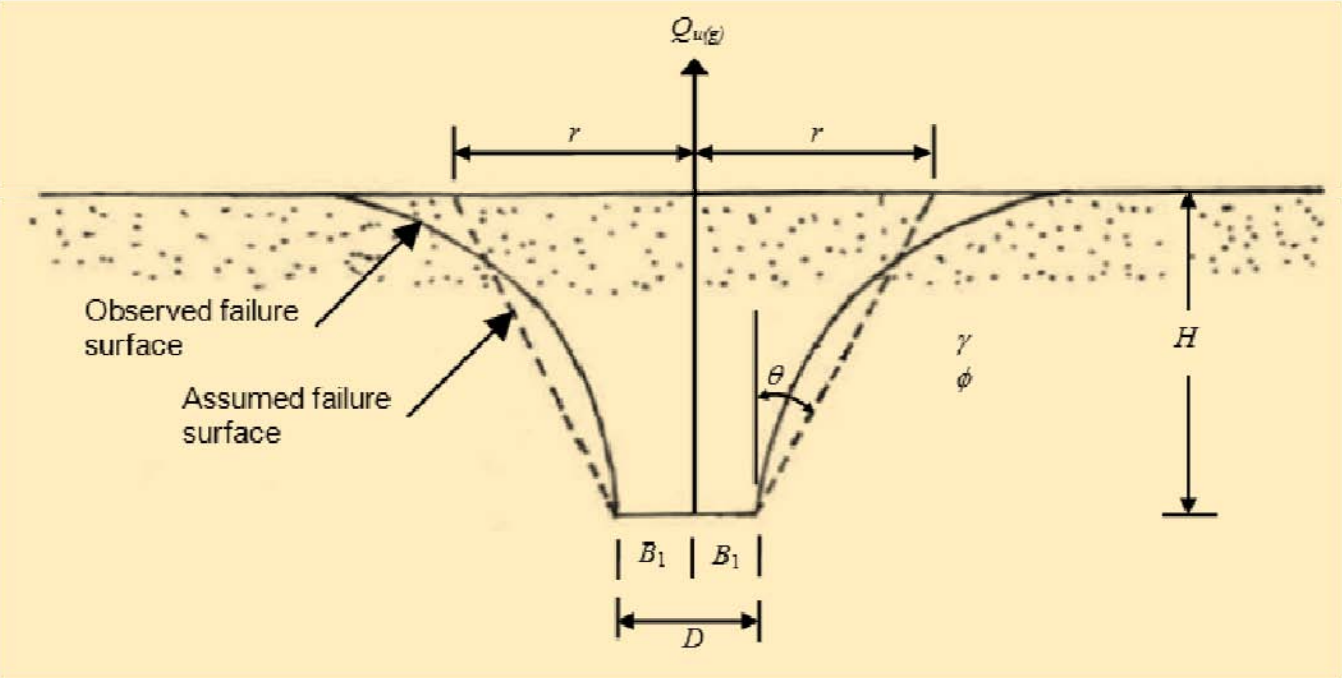


Fig. 6.4a

Deep screw anchor – assumed and observed failure surfaces (Sec. 6.2)

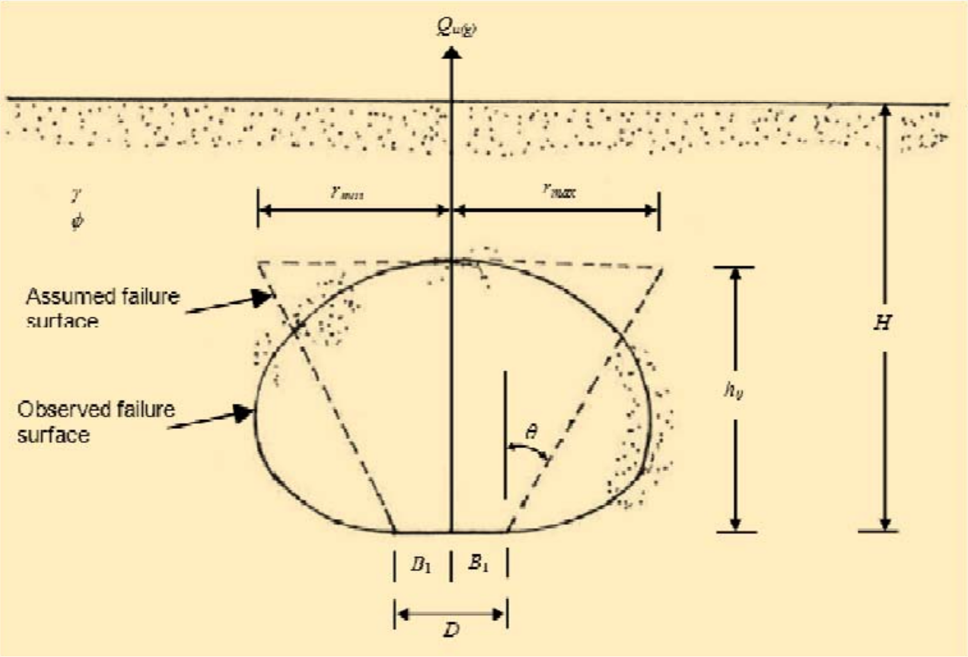


Fig. 6.4b

Transit screw anchor – assumed and observed failure surfaces (Sec. 6.2)

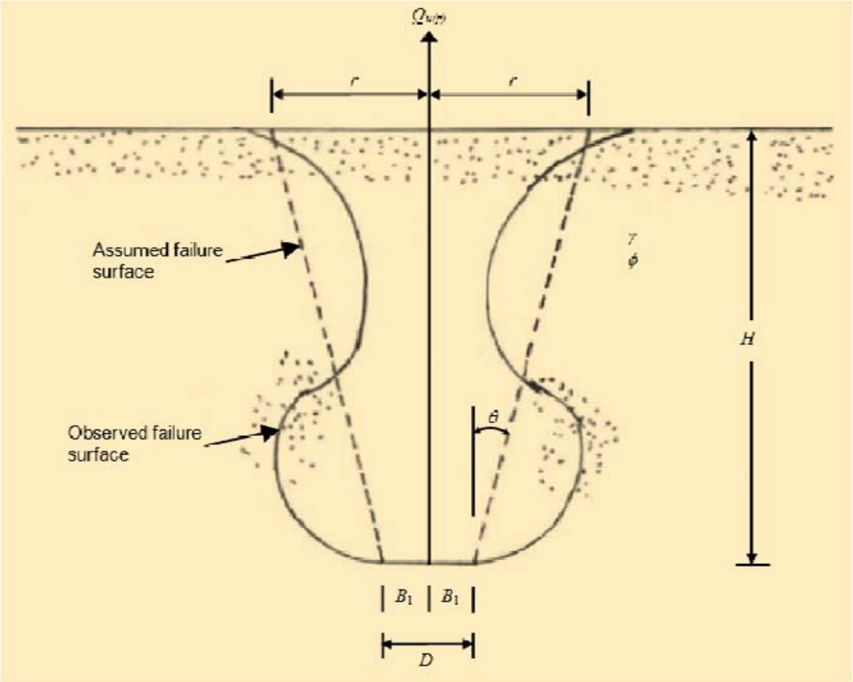
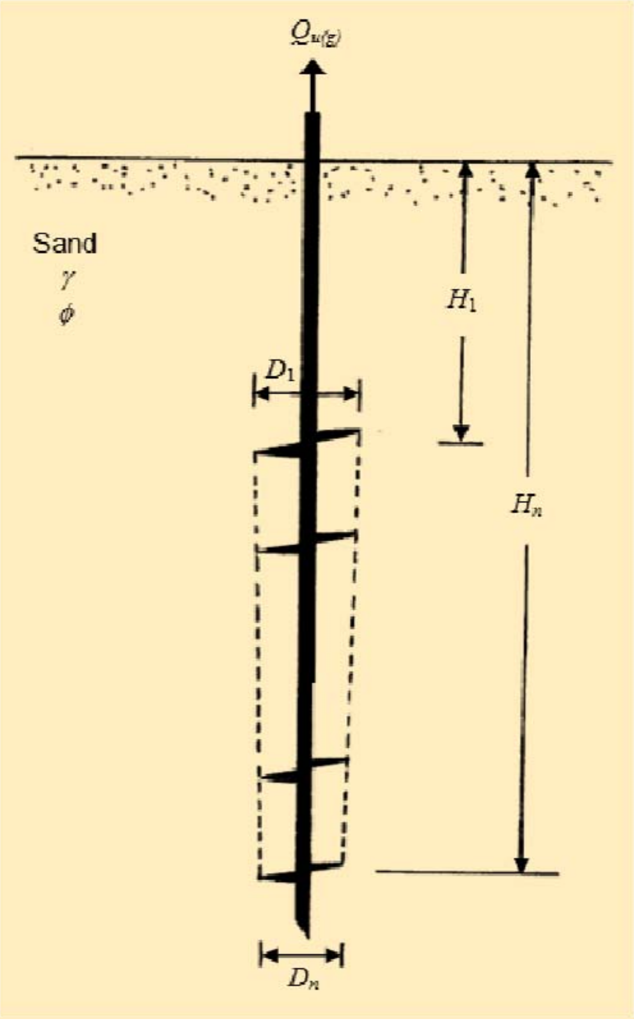


Fig. 6.4c

Multi-helix anchor (Sec. 6.3)



$$Q_{u(g)} = Q_u + W_a$$

Eq. (6.4)

Fig. 6.10

Multi-helix anchor – shallow anchor condition (Sec. 6.3)

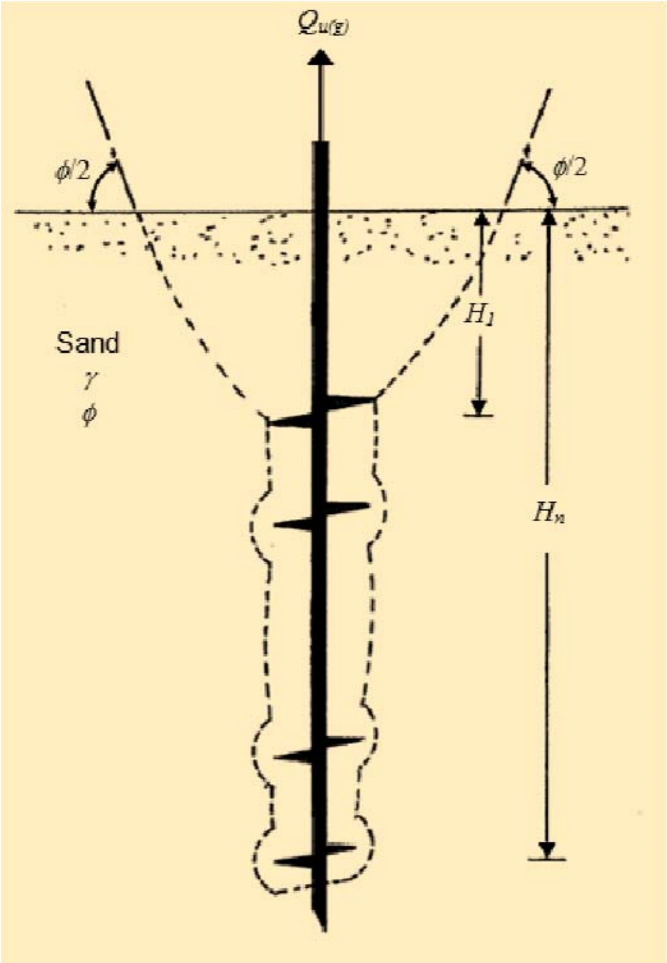


Fig. 6.11

Multi-helix anchor – deep anchor condition (Sec. 6.3)

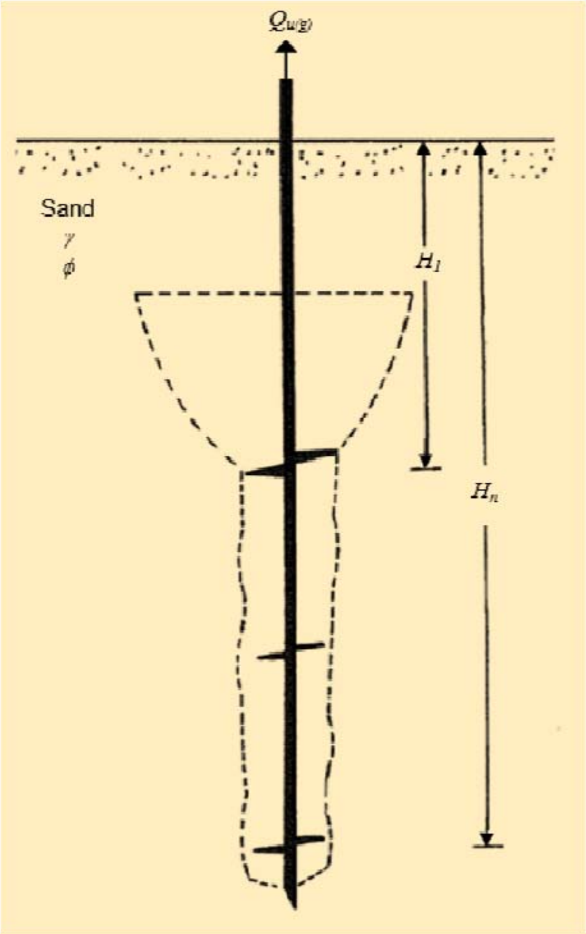


Fig. 6.12

Variation of breakout factor with H_1/D_1 (Sec. 6.3)

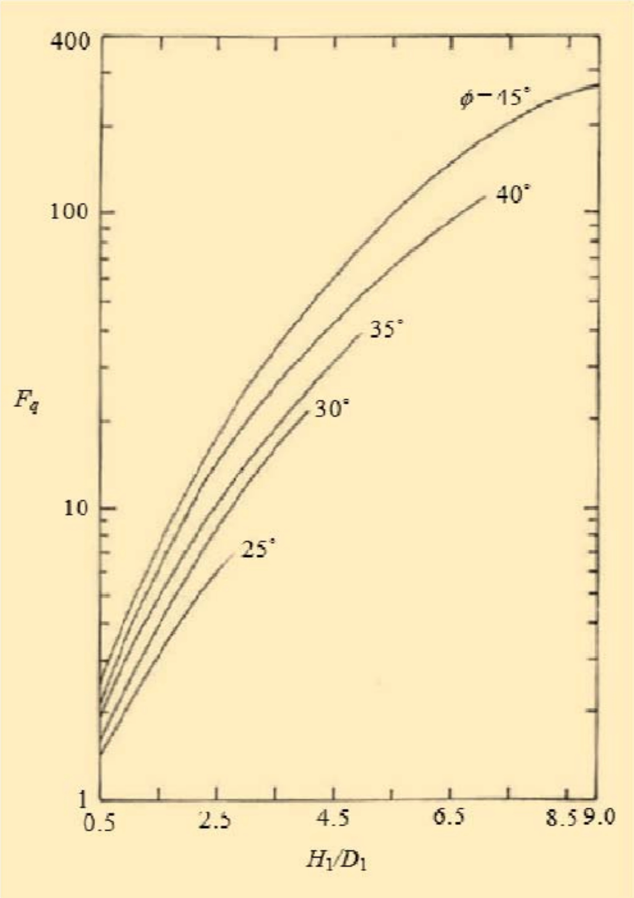


Fig. 6.17

Other studies (Sec. 6.5)

- Ghaly and Clemence (1998)
- Ghaly and Hanna (2003)

Can you list the major findings of recent developments?
(Compare your list with those described in Sec. 6.5)

Example 6.1

- Consider a screw anchor in sand similar to the one shown in Figure 6.2, where B_1 = 0.14 m, H = 2.24 m, ϕ = 38°, unit weight of sand γ = 16.5 kN/m^3. Estimate the net ultimate pull out load Q_u.

Answer: **252.2 kN**
(Find the complete solution on pages 217-218.)

Example 6.2

- Figure 6.18 shows a tapered multi-helix anchor. Given, for the sand: γ= 102 lb/ft^3 and ϕ = 35°. For the anchor: D_1 = 12 in., D_n= 7.5 in., H_1 = 3 ft, H_n = 10 ft. Determine the net ultimate uplift capacity.

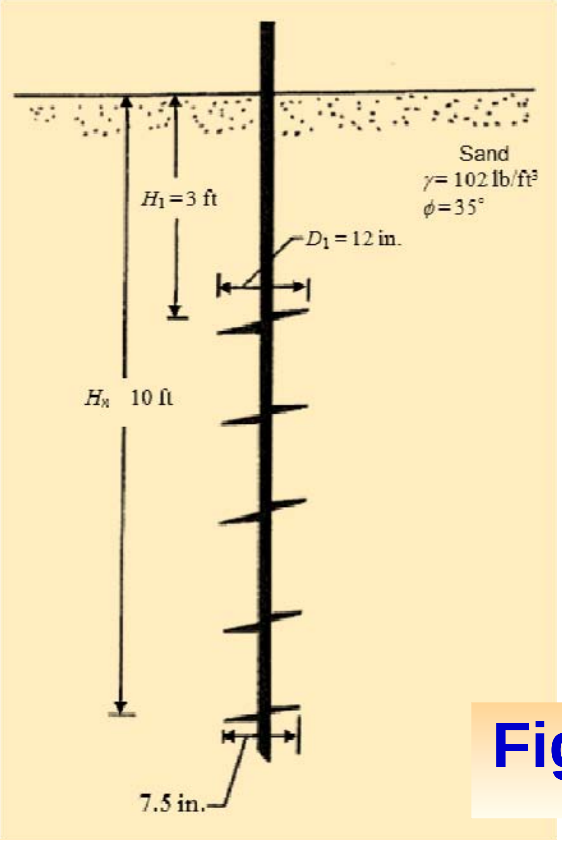


Fig. 6.18

Answer: **15,132 lb**
(Find the complete solution on pages 232-233.)

Summary of main points (Sec. 6.6)

- The shape of the single-helix (screw) anchor has practically no influence on the uplift capacity of the anchor.
- If helical anchors are placed too close to each other, the average net ultimate uplift capacity of each anchor may decrease due to the interference of the failure zones in soil located around the anchors.

Get more main points in Sec. 6.6.

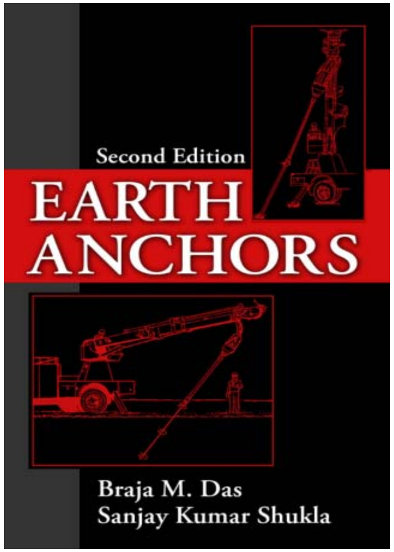
Self-assessment questions

1. Which of the following single-helix (screw) anchors fails in local shear failure:
 (a) shallow anchor
 (b) deep anchor
 (c) transit anchor
 (d) none of the above

2 For medium and loose sands, the anchor group efficiency:
 (a) increases with anchor spacing
 (b) decreases with group size
 (c) both a and b
 (d) decreases with anchor spacing

Get more questions and their answers on pages 238-239 of the book.

Chapter 7
Helical Anchors in Clay



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Helical anchors in clay (Sec. 7.1)

- Helical anchors are effective in resisting uplift forces in clay.
- They are usually installed into the clay in an economical manner by using truck-mounted augering equipment.

Uplift capacity (Sec. 7.3)

Shallow anchors:

$$Q_u = Q_p + Q_f$$ **Eq. (7.2)**

Deep anchors:

$$Q_u = Q_p + Q_f + Q_s$$ **Eq. (7.3)**

Variation of breakout factor F_c versus (Sec. 7.3)

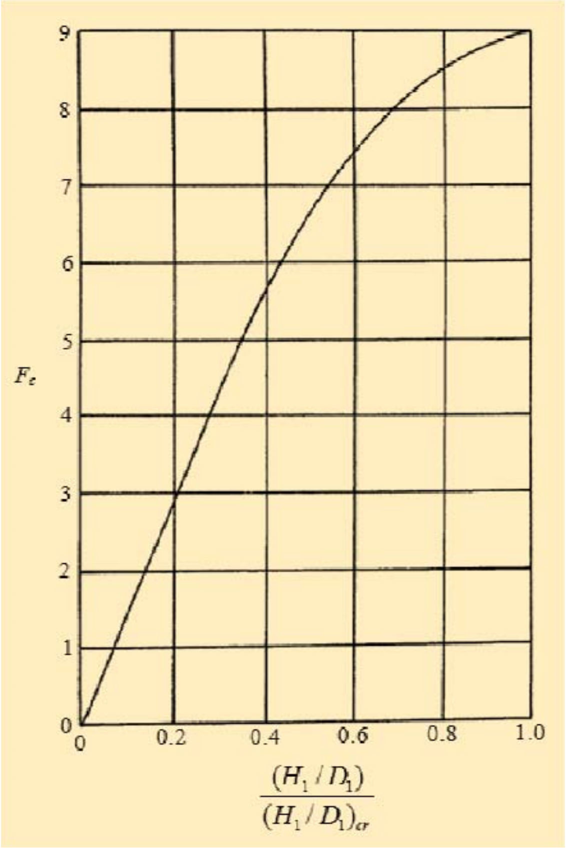


Fig. 7.3

?

Can you explain the importance of this plot?

Numerical modeling solution (Sec. 7.4)

- Merifield (2011) presented a numerical study based on ABAQUS displacement finite element software to understand the behaviour of the multi-helix anchor in clay.

$$Q_u = 3n\pi(1+\pi)\left(\frac{D^2}{4}\right)c_u$$

Eq. (7.11)

Use of in situ tests (Sec. 7.5)

- To determine the soil shear strength parameters for prediction of the net ultimate uplift capacity of multi-helix anchors.

Other studies (Sec. 7.6)

- Narasimha Rao et al. (1993)

?

Can you list the major findings?
(Compare your list with those described in Sec. 7.6)

Example 7.1

- Consider a multi-helix anchor embedded in a saturated clay where:

For the clay: $\gamma = 18.5$ kN/m^3

$c_u = 35$ kN/m^2

For the anchor: $D_1 = 0.4$ m; $D_n = 0.25$ m

$H_1 = 3$ m; $H_n = 7$ m

Diameter of the anchor shaft = 50 mm

Estimate the net ultimate uplift capacity.

Answer: **197.74 kN**

(Find the complete solution on page 248.)

Summary of main points (Sec. 7.7)

- Shallow and deep anchor conditions occur with small and large values of embedment ratio H_1/D_1, respectively.
- The numerical study shows that the cylindrical failure surface method overestimates the uplift capacity by as much as 70%.

Get more main points in Sec. 7.7.

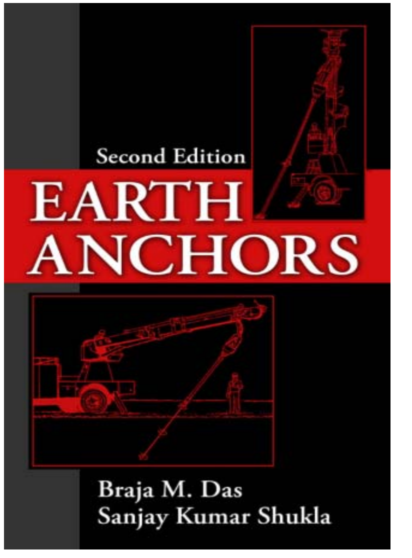
Self-assessment questions

1. The failure surface located above the top helix of a multi-helix anchor extends to the ground under:
 (a) shallow anchor condition
 (b) deep anchor condition
 (c) both a and b
 (d) none of the above

2 The magnitude of the breakout factor increases with embedment ratio H_1/D_1 to a maximum value of:
 (a) 3
 (b) 6
 (c) 9
 (d) 12

Get more questions and their answers on pages 251-252 of the book.

Chapter 8
Anchor Piles



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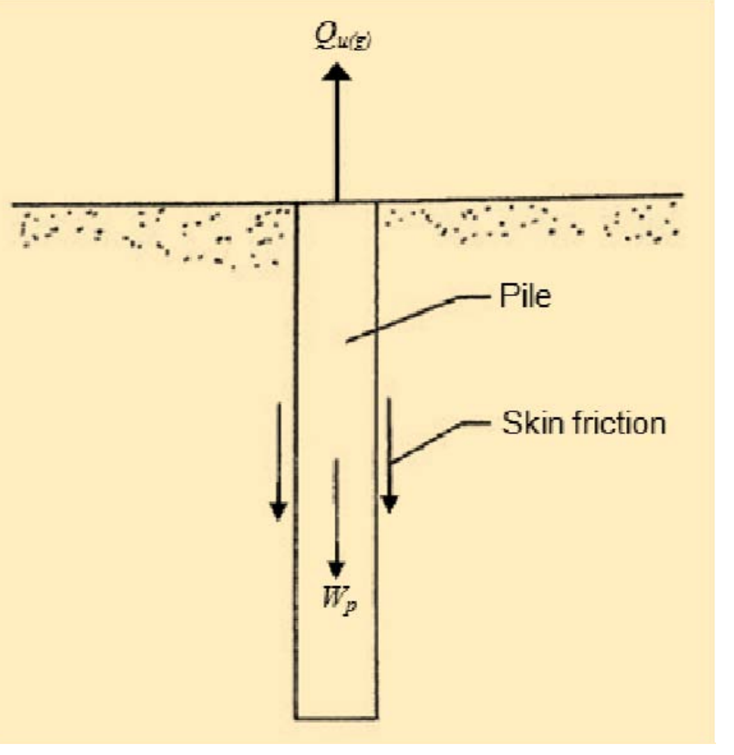
Uses of Anchor Piles (Sec. 8.1)

- To transmit downwardly directed load to a stronger soil at a greater depth.
- To resist lateral load imposed on a foundation.
- To resist uplifting forces.

Uplift capacity (Sec. 8.1)

$$Q_{u(g)} = Q_u + W_p$$

Eq. (8.1)



Piles in sand (Sec. 8.2)

- Bored piles (Sec. 8.2.1)
- Driven piles (Sec. 8.2.2)

Cross sections of piles

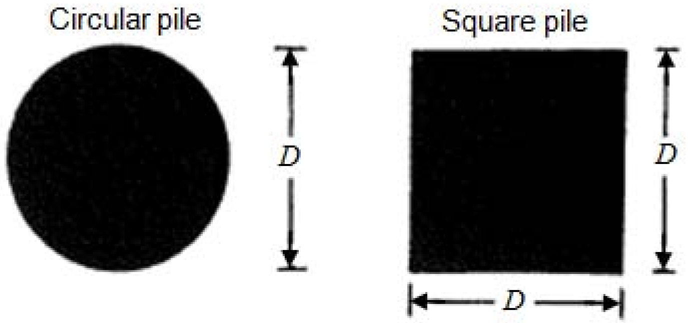


Fig. 8.10

Uplift capacity of inclined piles subjected to axial pull (Sec. 8.2.3)

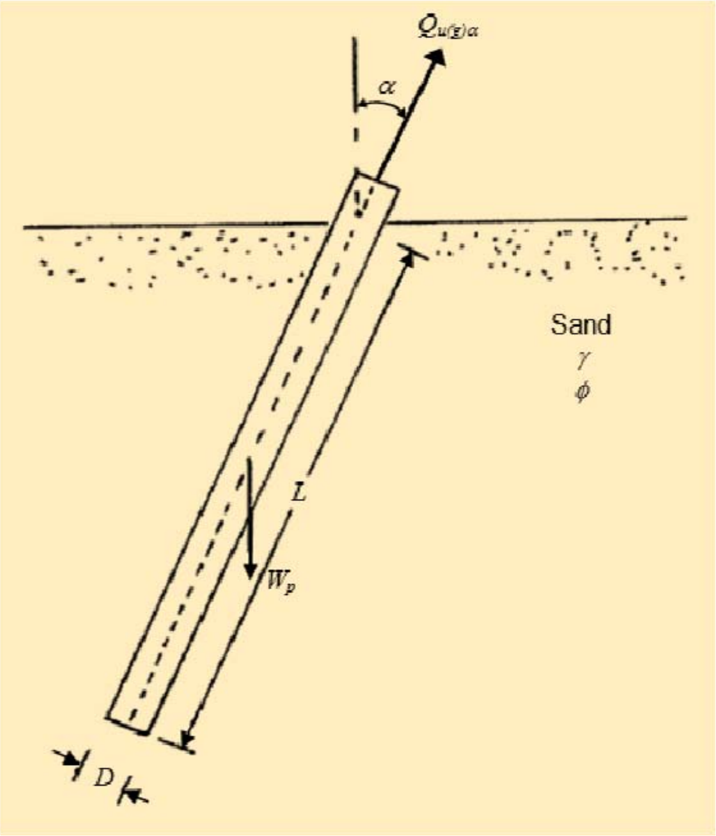


Fig. 8.14

Uplift capacity of group of piles (Sec. 8.2.5)

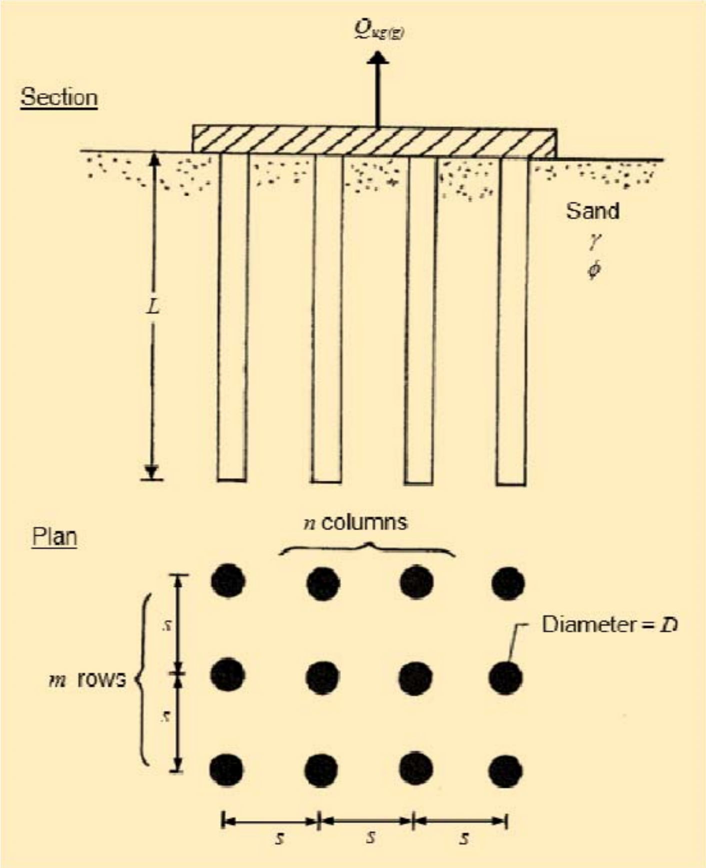


Fig. 8.23

Piles in clays (ϕ = 0 condition) (Sec. 8.3)

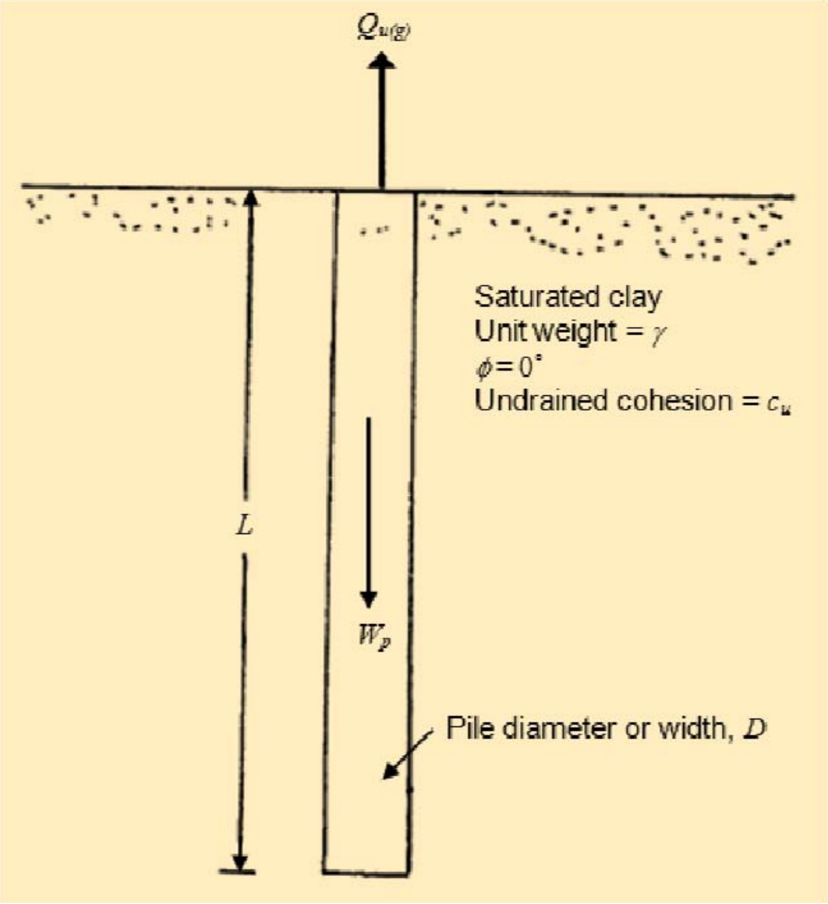


Fig. 8.26

Uplift capacity of group of piles in clay (Sec. 8.3.5)

- For a given clay (that is, c_u), L/D, and number of piles in a group, the magnitude of η increases linearly with s/D.
- For a given s/D ratio and clay, the group efficiency decreases with the increase of the number of piles ($m \times n$) in the group.
- For a given clay soil (that is, c_u) and number of piles in the group, the efficiency decreases with the increase of the L/D ratio.
- For a given L/D ratio, number of piles in a group, and s/D, the increase of c_u results in a decrease of the magnitude of the group efficiency.

Example 8.1

- Consider a pile having a circular cross section with a diameter D = 0.4 m and length of embedment L = 10 m (Figure 8.12). Given, for the sand: ϕ = 43°, D_r = 75%, γ= 17.5 kN/m^3. Determine the net ultimate uplift capacity.

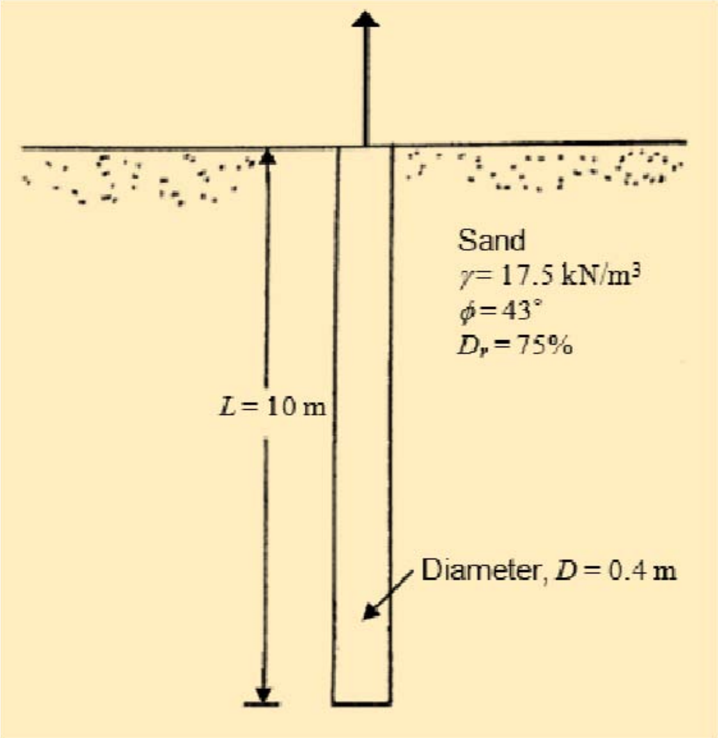


Fig. 8.12

Answer: **487.7 kN**
(Find the complete solution on pages 264-265.)

Example 8.7

- A vertical concrete pile having a square cross section of 0.3 m × 0.3 m and a length of 8 m is embedded in a saturated clay having an undrained cohesion of 60 kN/m^2. Estimate the net ultimate uplift capacity.

Answer: **302.4 kN**
(Find the complete solution on pages 29-291.)

Summary of main points (Sec. 8.4)

- The net ultimate uplift capacity of a pile embedded in sand is primarily a function of the following parameters: length of embedment, pile diameter, roughness of pile surface, soil friction angle, soil relative density, and nature of placement of the pile (driven, bored or cast-in-place).
- Under similar conditions, the net ultimate uplift load of the pile is somewhat lower than that of the horizontal plate anchor.

Get more main points in Sec. 8.4.

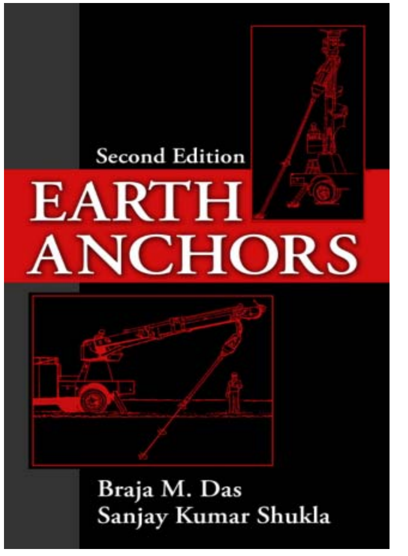
Self-assessment questions

1. The critical embedment ratio of an anchor pile in dense sand is about:
 (a) 3.5
 (b) 10.0
 (c) 14.5
 (d) none of the above

2 The net ultimate capacity of an anchor pile in clay is directly proportional to the:
 (a) perimeter of the pile cross section
 (b) pile length
 (c) adhesion at the pile-clay interface
 (d) all of the above

Get more questions and their answers on pages 299-300 of the book.

Chapter 9
Suction Caisson and Drag Anchors



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Suction Caisson Anchors – Basic Details (Sec. 9.2)

- The vast majority of modern suction caisson anchors consist of large diameter, typically in the range of 3 to 8 m, internally stiffened thin-walled steel cylindrical cells, open at the bottom and closed on the top

Suction Caisson Anchors – Design Issues (Sec. 9.2)

- Design for installation
- Design for operational conditions

See the details on pages 302-304

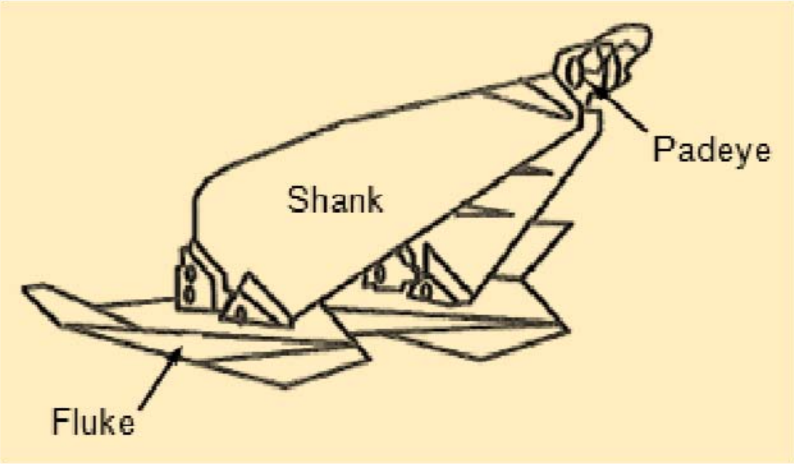
Suction Caisson Anchors – Uplift Capacity (Sec. 9.2)

- With passive suction
- Without passive suction

Drag anchors – basic details (Sec. 9.3)

- A traditional drag anchor (also called fixed fluke plate anchor) consists of a broad fluke rigidity connected to a shank, as shown in Fig. 9.5.

Fig. 9.5



Drag anchors – design issues (Sec. 9.3)

- Empirical designs
- Most rational approaches are based on limit equilibrium and kinematic analyses
- A detailed investigation requires a full 3D analysis
- To avoid working on a complex analysis, it is a general practice to assume that the fluke provides a large proportion of the anchor's holding capacity and governs much of the anchor's kinematics.

Drag force components (Sec. 9.3)

- Base bearing
- Skin adhesion of the base
- Skin adhesion of the sides

See the details on pages 308-309.

Summary of main points (Sec. 9.4)

- Suction caisson and drag anchors are two most common anchor types used in deep waters for offshore floating structures.
- When a drag anchor approaches its ultimate holding capacity in soft undrained soils, failure of soil can be assumed to consist of localized plastic flow around the anchor fluke and shank.

Get more main points in Sec. 9.4.

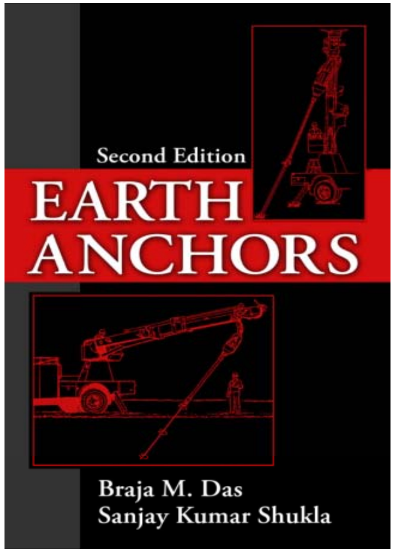
Self-assessment questions

1. The initial settlement of the suction caisson anchor is by:
 (a) its self weight
 (b) under pressure created by pumping water out
 (c) under pressure created by pumping air out
 (d) both a and b

2. Anchor forces for a given depth and fluke angle are calculated by solving four equations, out of which how many equations are force equilibrium equations:
 (a) 1
 (b) 2
 (c) 3
 (d) 4

Get more questions and their answers on pages 311-312 of the book.

Chapter 10
Geo-Anchors



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Two forms of geo-anchors (Sec. 10.1)

- Geotextile-wrapped anchors
- Trench anchors

Geotextile-wrapped anchors –basic details (Sec. 10.2)

- A geotextile-wrapped anchor consisting of a permeable core of coarse sand, gravel or crushed stone wrapped in one or several layers of high-strength woven geotextiles can be used to increase the stability of steep slopes, to reduce the lateral earth pressures on retaining structures or to stabilize embankments constructed on soft clay.

Geotextile-wrapped anchors – computation of design tensile reinforcement (Sec. 10.2)

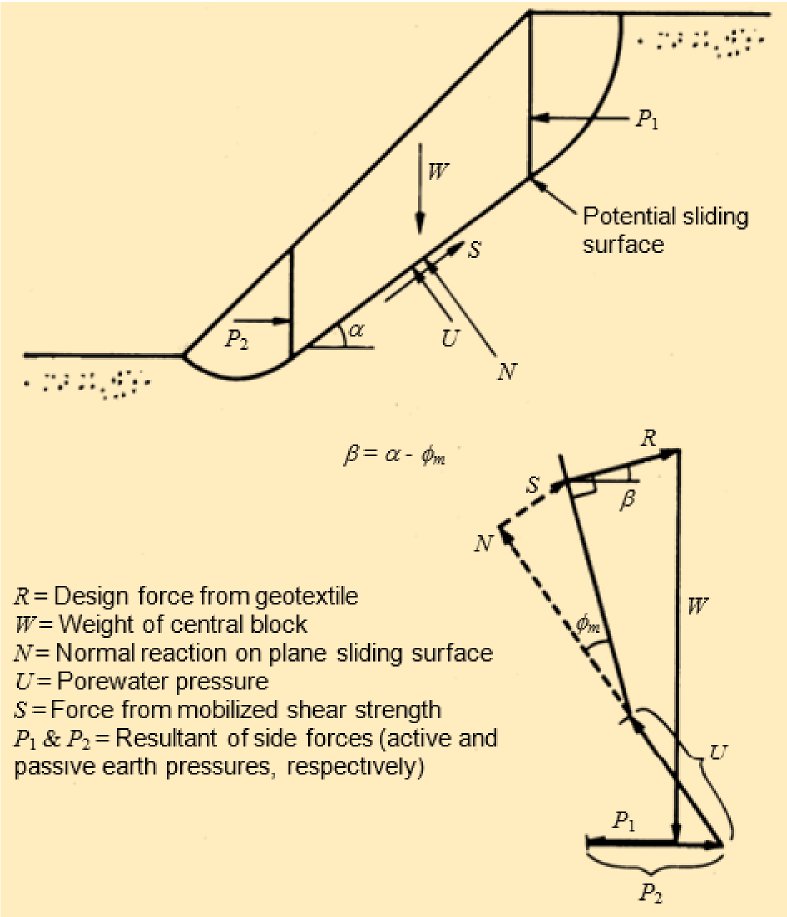


Fig. 10.3

Trench anchors – basic details (Sec. 9.3)

- The trench anchor is commonly used for firmly securing the geosynthetic layer installed as a pond/canal liner or slope surface protection so that the geosynthetic movement or pullout does not occur during installation and operation of the system.

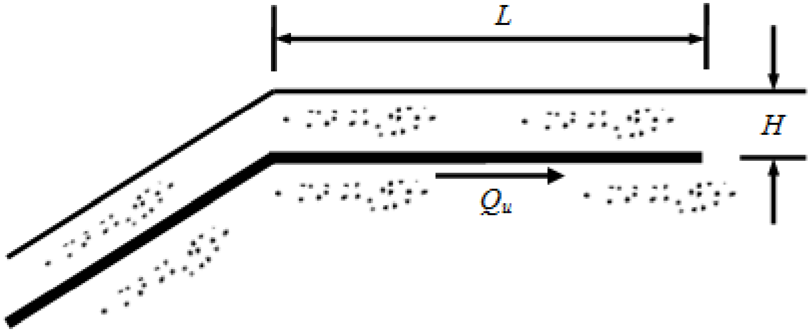
Trench anchors – Types (Sec. 9.3)

- Simple runout anchor
- Rectangular trench anchor
- V-trench anchor
- Narrow trench anchor

See Fig. 10.6 for more details on page 319.

Trench anchors – Notations used to develop design equations (Sec. 9.3)

Fig. 10.8a



See more details on pages 321-323.

Summary of main points (Sec. 10.4)

- Compaction of the granular fill in geotextile-wrapped anchors should be done in the downhill direction in order to pretension the geotextile layer.
- Since the overlying soil may crack and move along with geosynthetic layer, the ultimate pullout capacity of runout and trench anchors should be calculated considering only the resistance on the underside of the geosynthetic layer.

Get more main points in Sec. 10.4.

Self-assessment questions

1. The geotextile layer in geotextile-wrapped anchors acts as:
 (a) a filter
 (b) a reinforcement
 (c) both a and b
 (d) a drain

2. Which of the following does not require a lot of room:
 (a) runout anchor
 (b) rectangular trench anchor
 (c) V-trench anchor
 (d) both b and c

Get more questions and their answers on pages 324-325 of the book.

THANK YOU