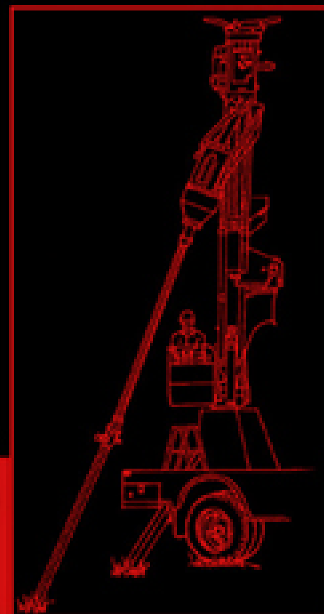
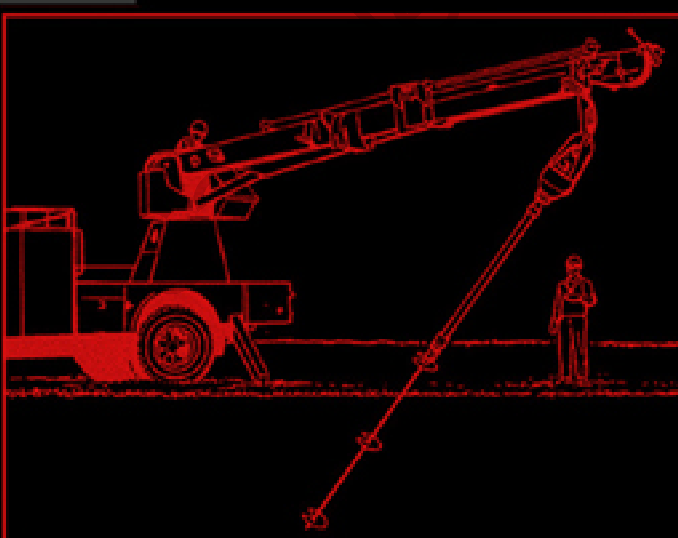
Second Edition

EARTH ANCHORS





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HELICAL ANCHORS IN SAND

At the present time, limited studies on helical anchors are available, the results of which can be used to estimate their ultimate uplift capacity. In many instances, the ultimate load estimate is based on rule of thumb. This chapter summarizes the existing theories relating to the prediction of the net ultimate uplift capacity of single-helix (screw) anchors and tapered multi-helix anchors embedded in sandy soils.

6.1 INTRODUCTION

Basic descriptions of helical anchors and their two main types, *single-helix (screw) anchors* and *multi-helix anchors*, are presented in Section 1.4. Figures 1.8 and 1.9 are photographs of helical anchors with single and dual helices, which are generally used for light to medium loads. However, at the present time, tapered multi-helix anchors (three to four helices) are commonly used to carry uplift loads up to about 550 to 600 kN. Figure 6.1 shows the typical dimensions of a multi-helix anchor used in the United States for construction of foundations of electrical transmission towers. These anchors are fairly easy to install and, hence, are cost effective.

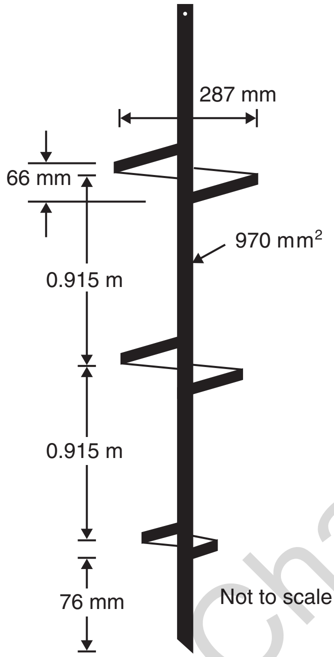

FIGURE 6.1 Typical multi-helix anchor used in the United States

6.2 SINGLE-HELIX (SCREW) ANCHORS

6.2.1 Ultimate Holding Capacity of Single-Helix (Screw) Anchors

Ghaly et al. (1991) presented experimental and theoretical investigations on the behavior of single-helix (screw) anchors in sand. Their laboratory testing program included 56 tests conducted on five model anchors installed in dense, medium, and loose dry sands. The screw elements were fabricated from high-quality mild steel as one unit, with no welded joints. The geometrical dimensions of one of the anchors used for testing dense sand are shown in Figure 6.2. The experimental setup was instrumented to allow the measurement of the pullout load and the upward displacement of the anchor and the deflection of the sand surface.

The experimental results show that the shape of the screw anchor has little effect or no influence on the uplift capacity of the anchor. For a given type of sand, the diameter of the first blade ($D = 2B_1$) of the screw element and the

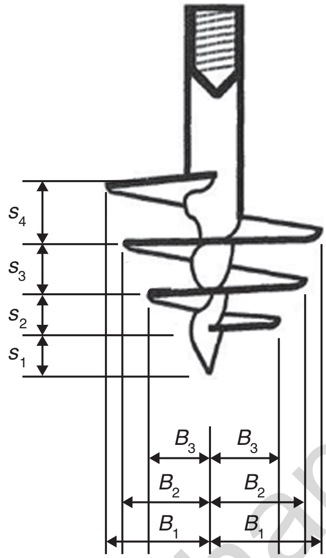

FIGURE 6.2 Dimensions of screw anchors used by Ghaly et al. (1991) (B_1 = 25 mm, B_2 = 20 mm, B_3 = 15 mm, s_1 = 7.5 mm, s_2 = 9 mm, s_3 = 12 mm, and s_4 = 15 mm)

anchor installation depth are the main factors that affect the pullout behavior. Typical pullout load versus upward displacement (u) curves for screw anchors installed in dense sand are shown in Figure 6.3. In this figure, H is the depth of the first blade from the ground surface. It has been observed that for a given installation depth, the pullout capacity increased with the increase in the value of the angle of shearing resistance; this effect is more at greater depths.

Figure 6.4 shows three modes of failure at ultimate load, on the basis of which the screw anchors were classified as (a) shallow screw anchor, (b) deep screw anchor, and (c) transit screw anchor. Shallow screw anchors fail in general shear failure and deep screw anchors in local shear failure. In the case of transit screw anchors, there is no clear distinction between shallow and deep anchors; thus a transit screw anchor in pullout fails under a combined failure mechanism. Figure 6.5 shows the variation of H/D with soil friction angle (ϕ) for shallow, transit, and deep anchors.

Assuming planar surfaces as shown in Figure 6.4, Ghaly et al. (1991) presented the expressions for the ultimate pullout capacity of shallow, transit, and deep screw anchors. They also assumed the following:

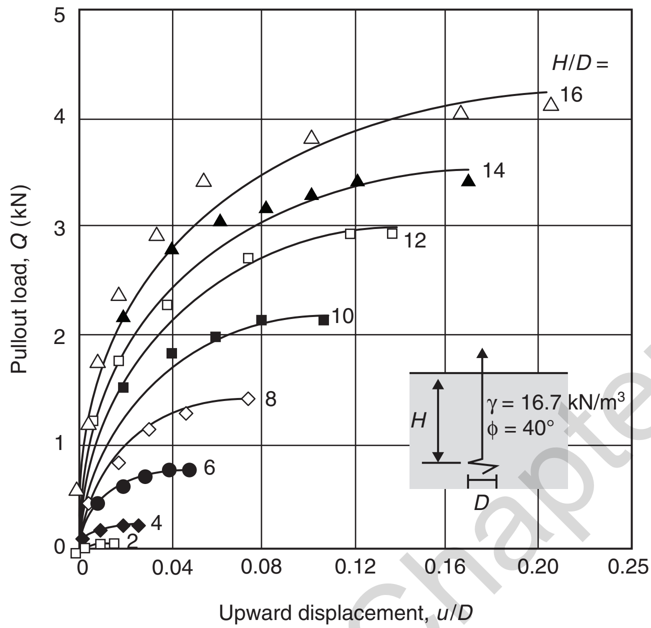

FIGURE 6.3 Typical pullout load versus upward displacement relationship for tests in dense sand ($D = 2B_1 = 50$ mm) (adapted from Ghaly et al., 1991)

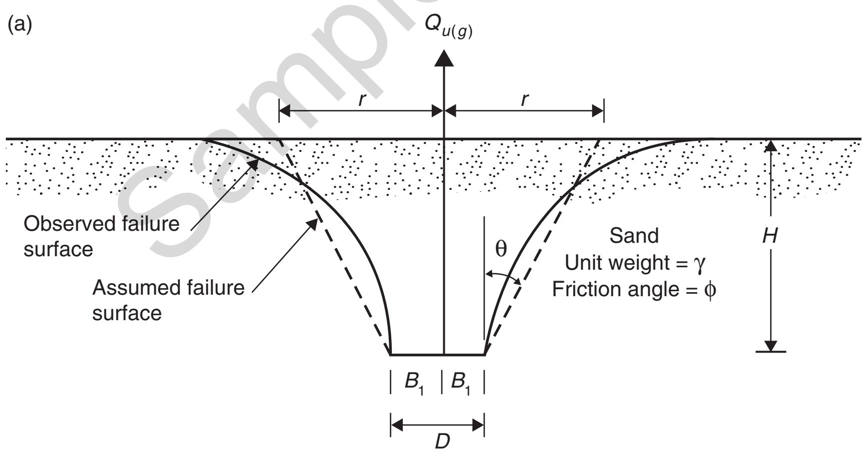

FIGURE 6.4 Assumed and observed failure surfaces in sand based on the study by Ghaly et al. (1991): (a) shallow screw anchor, (b) deep screw anchor, and (c) transit screw anchor

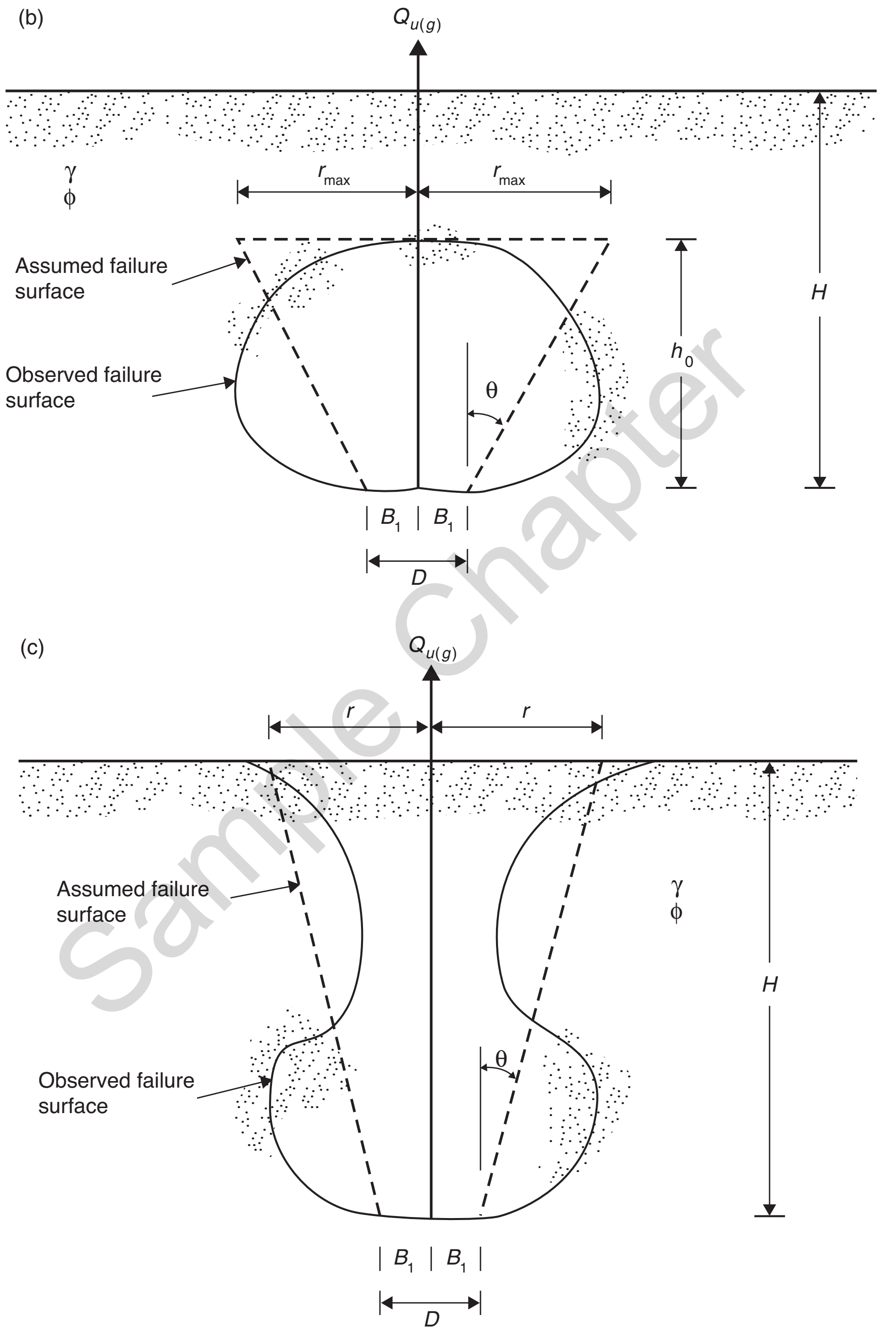

FIGURE 6.4 (continued)

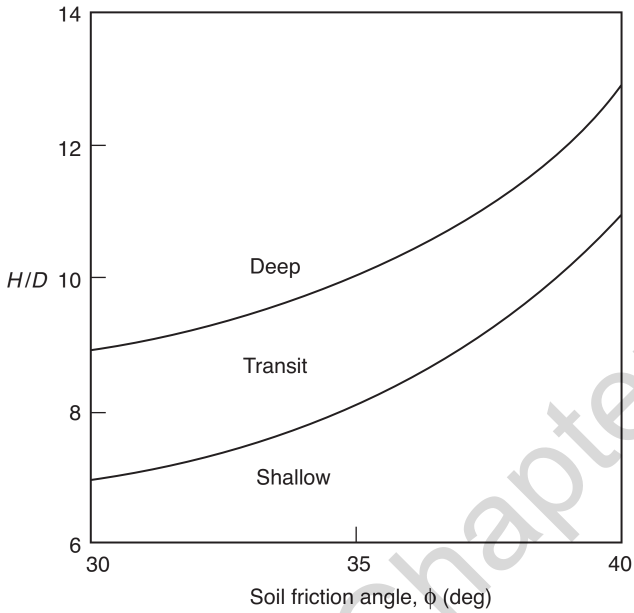

FIGURE 6.5 Variation of H/D with soil friction angle ϕ for shallow, transit, and deep anchors

1. The sand is homogeneous and isotropic, and it behaves in a nonlinear stress-strain relationship.
2. The disk of the screw anchor is thin and rigid, so that its deformation is negligible.
3. The screw anchor is in full contact with the surrounding sand medium.
4. There is no significant friction to be considered either on the tie-rod or on the surface of the screw blade.

For shallow or transit screw anchors:

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

$$= \frac{\pi}{2}\gamma H^2 K_p' \left(\frac{D + H\tan\theta}{\cos\theta}\right)\tan\delta + \underbrace{\frac{\pi}{3}\gamma H(B_1^2 + r^2 + B_1 r)}_{W} \qquad (6.1)$$

where