DESIGN AND CONSTRUCTION OF SOIL ANCHOR PLATES

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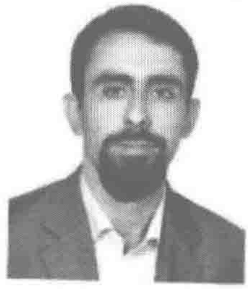

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PREFACE

Anchor plates are geotechnical devices that have been constructed to support geotechnical structures. They are devised to prevent the overturning of structures experiencing lateral, inclined, and uplift loads. Anchor plates can be applied in a wide variety of uses, such as stabilization systems in foundations, retaining walls, sea walls, and pipe lines. In this book, we have focused on the structural design of anchor plates, their uplift and bearing capacity, as the anchors are primarily designed to resist outwardly-directed loads imposed onto the foundation(s) of structures.

This book consists of three main sections. The first section gives an introduction to all types of earth anchors. The second section gives calculation equations and outlines the requirements of anchor plates for use in sandy soils, and plates embedded in clays. The third section explains all the features of anchor plates that can be used in multilayer soils. Throughout the text, we compare and contrast some of the current theories and modeling for calculating the capacity of anchor plates. Alongside the textual elements, this book also contains several examples and photos to help illustrate the details of anchor plates and their usage. We have aimed to present the information in a user-friendly manner that is easy to follow and practice.

The book contains nine chapters. Chapters "Anchors" and "Anchor Plates" describes and review all the types of earth anchors that have geotechnical applications. Chapters "Horizontal Anchor Plates in Cohesionless Soil" and "Horizontal Anchor Plates in Cohesive Soil" investigate horizontal anchor plates as used in various types of soils such as clays and sands—both their features and their capacity. Chapters "Vertical Anchor Plates in Cohesionless Soil" and "Vertical Anchor Plates in Cohesive Soil" present some useful information regarding vertical anchor plates. These chapters describe the various types of vertical anchor plates, their capacity, and their common applications. Chapters "Inclined Anchor Plates in Cohesionless Soil" and "Inclined Anchor Plates in Cohesive Soil" describe inclined anchor plates and their usage in different types of soil such as clays and sands. These chapters describe the installation process and detail the capacity of inclined anchor plates, including examples where relevant. Chapter "Anchor Plates in Multilayer Soil" describes the use of anchor plates in multilayer soils.

The authors of this book hope that they have succeeded in providing readers with useful information about different types of anchor plates, given that they have a wide variety of application in crucial construction projects such as retaining walls, sea walls, and foundations of structures. Thus, the authors hope that this book fosters the further development of anchor plates and optimization of their applications.

Hamed Niroumand

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CHAPTER 1

Anchors

1.1 INTRODUCTION

The choice of foundation systems has an important role in the design of many structures, to ensure they support any vertical or horizontal loads. Structures such as seawalls, transmission towers, tunnels, buried pipelines, and retaining walls are subjected to pullout forces and overturning moments. Thus, in the building process, the development of guidelines for the design and installation of anchor systems is one way to improve the performance of foundation systems.

For structures such as we mentioned above, using tension members can prove to be an economic design solution. Tension members are a type of soil anchor, and can also be used for tieback resistance in waterfront structures, pressure soil structures, and also against thermal stresses. Tension members should be fixed to the structure and then embedded into the ground to a considerable depth in order to resist uplifting forces.

In general, soil anchors are foundation systems used to transmit forces from the structure to the ground, in order to resist overturning moments and pullout forces which can threaten a structure's stability. The shear strength and dead weight of the soil surrounding an anchor are factors that improve an anchor's strength. Traditionally, soil anchors were divided into only three categories: grouted anchors, helical anchors, and anchor plates; however, a new self-driven anchor placed into the ground without excavation and grout has also been recently added to the list. According to the method of load transfer from the anchor to the surrounding soil, types of soil anchors in geotechnical engineering can be categorized as

- Grouted anchors
- Helical anchors
- Anchor plates
- Anchor piles
- Irregular shape anchors, used as self-driven anchors.

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1.2 GROUTED ANCHORS

A grouted soil anchor is installed in grout-filled drilled holes in the soil or rock and transmits an applied tensile load into the soil or rock. Grouted anchors are structural elements where a grout body is installed in the subsoil or rock by injecting grouting mortar around the rear part of the steel tendon. The grouted body is connected to the structure, or the rock section to be anchored, using steel or fiber tendon(s) and the anchor head. Any load to be taken up by the grouted anchor is passed into the subsoil, instead of over the entire length of the anchor, but only in the area of the grouted body. The steel tendon section, where the soil anchor is free to expand, is the free tendon length. This section acts like a spring that can be pretensioned to the structure against the subsoil.

Grouted anchors are subjected to tension only and their load capacity is checked by tensioning. Bonded deep into the ground using cementatious grout, these soil anchors transfer the necessary forces to restrain walls from overturning, water tanks and towers from uplifting forces, dams from rotating and other naturally- or phenomenally occurring forces applied to structures. The grouted anchor capacity is a function of the steel capacity as well as the geotechnical holding capacity. The steel capacity should be limited to 80% maximum test load and 60% lock-off load for permanent applications. However, the geotechnical holding capacity is a function of the ground bond stress characteristics that can be optimized by field procedures. Mainly, the cementation of a grouted body ensures a radial tie-in of the anchor tendon in the soil and also provides simple corrosion protection.

A grouted anchor consists of two zones:

- Anchor bond zone: The length along which the grout adheres to the soil and results in load transfer that can be placed above the tendon bond zone.
- Tendon bond zone: The length along which the bar/tendons are bonded to the grout and transfer the load.

The basic components of a grouted anchor are:

- Anchorage
- Free stressing length
- Bond length.

The anchorage consists of the anchor head, bearing plate, and the trumpet that transmits the prestressing force from the prestressing steel to the soil or the structure (Figs. 1.1 and 1.2).

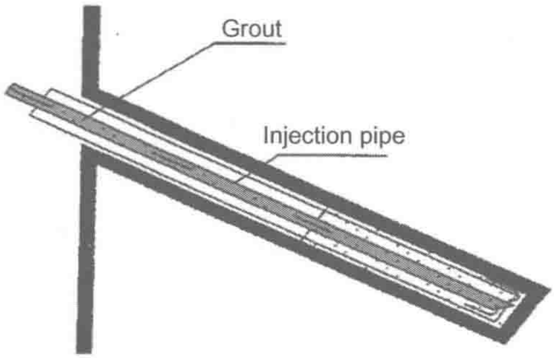

Figure 1.1 A grouted anchor.

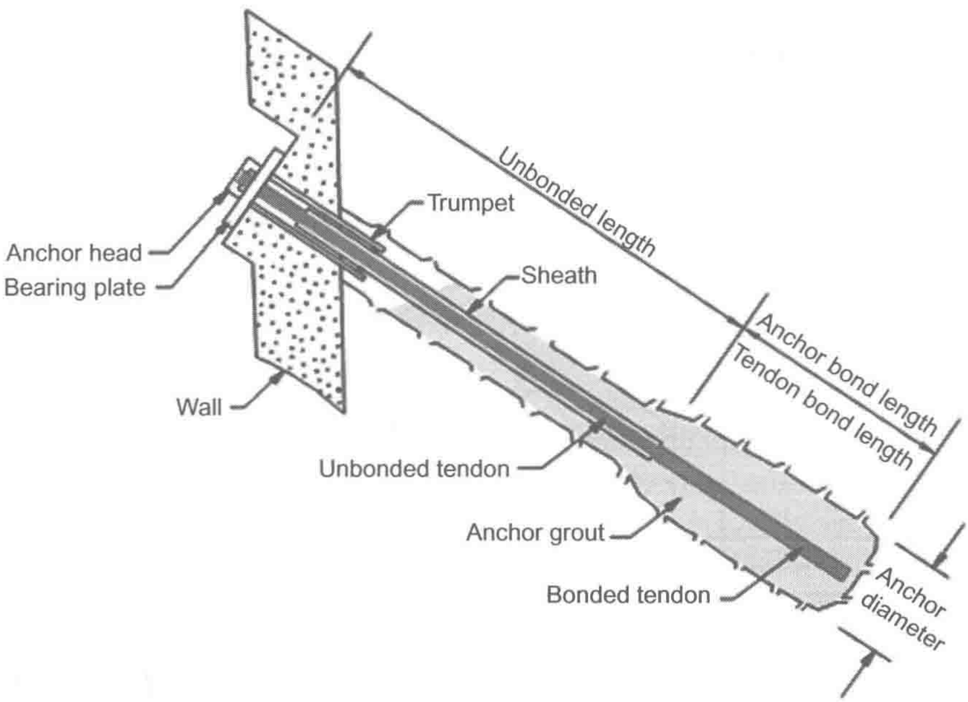

Figure 1.2 Components of a grouted anchor.

Four types of grouted anchors (Fig. 1.3) commonly used by engineers are

- Straight shaft gravity grouted anchors
- Straight shaft pressure grouted anchors
- Postgrouted anchors
- Under reamed anchors.

Each of the four types of grouted anchor is best suited to a specific purpose. For example, straight shaft pressure grouted anchors are used for coarse granular soils or weak and weathered rocks. In postgrouted

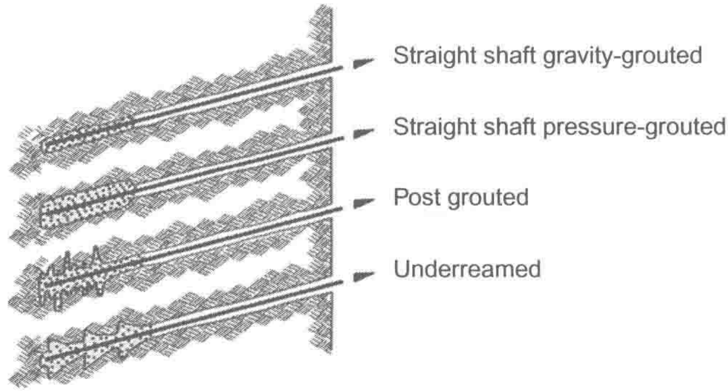

Figure 1.3 Four types of grouted anchors.

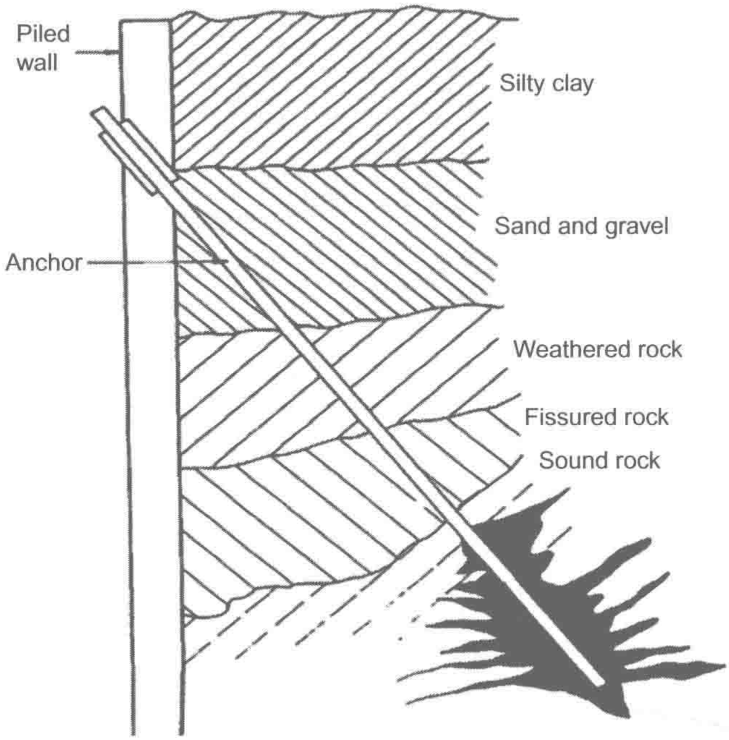

Figure 1.4 Grouted anchors used in sea walls.

anchors, in order to enlarge the body of the straight shaft gravity grouted anchors, multiple grout injections are used. On the other hand, the capacity of grout anchors under compression or tension is based on the bearing capacity of the soil or the structure in which they are installed.

Grouted anchors can be used in different geotechnical projects such as seawalls (Fig. 1.4), retaining walls (Fig. 1.5) and the foundation of pipelines and transmission towers to aid resistance against overturning.

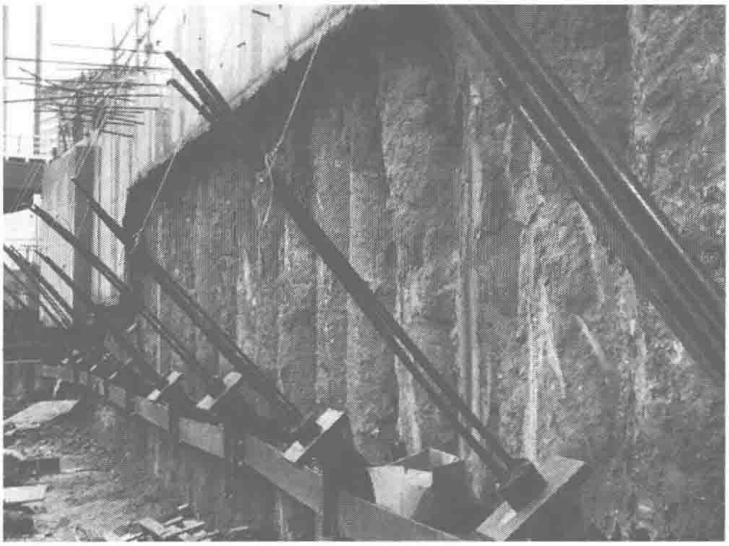

Figure 1.5 Grouted anchors used in retaining walls.

1.3 HELICAL ANCHORS

Helical anchors have been used in the earth-boring industry for more than 170 years and bring "new" solutions to the soil stabilization and foundation industry. Sporadic use of helical anchors has been documented throughout the 19th and early 20th centuries, mainly for supporting structures and bridges built upon weak or wet soil. When hydraulic motors became readily available in the 1960s, allowing for easy and fast installation of helical anchors, their popularity flourished. Electric utility companies began to use helical anchors for tie down anchors on transmission towers and for guy wires on utility poles. Helical anchors are ideal for applications where there is a need to resist both tension and axial compression forces. Some examples of structures with a combination of these forces are metal buildings, canopies, and monopole telecommunication tower foundations. Current uses of helical anchors include underpinning foundations for commercial and residential structures, foundation repair, light standards, retaining walls, tieback anchors, pipeline and pumping equipment supports, elevated walkways and bridge abutments, along with numerous uses in the electric utility industry (Niroumand et al., 2013). Often helical anchors are the best solution for a foundation repair project because of one or more of the following factors:

- Ease of installation
- Little to no vibration
- Immediate load transfer upon installation

- Installed torque correlates to capacity
- Load easily tested to verify capacity
- Installs below active soils
- Can be installed in all weather conditions
- Little to no disturbance to the job site.

Helical anchors are used to resist tensile loads. Under downward-loading conditions, helical anchors can supply additional bearing capacity to the foundation. Helical anchors are screw forms combined with steel shafts and a series of helical steel plates that are attached to a pitch and are screwed into the soil until there is enough torque resistance to support the tieback wall systems and soil nail wall systems. Screw anchors are used for resistance in front of vertically uplifting loads in soils (Figs. 1.6–1.8). They can be installed in inclined and vertical positions. To reduce the disturbance in the soil, multiple helical anchors can be used, in which the upper helical anchors follow the lower ones.

A helical anchor is a deep, segmented foundation system with helical bearing plates welded to a central steel shaft. The load is transferred from the shaft to the soil through these bearing plates. Helical plates are spaced at distances far enough apart so that they can function independently as individual bearing elements. Consequently, the capacity of a particular helix

Figure 1.6 A single helix anchor.

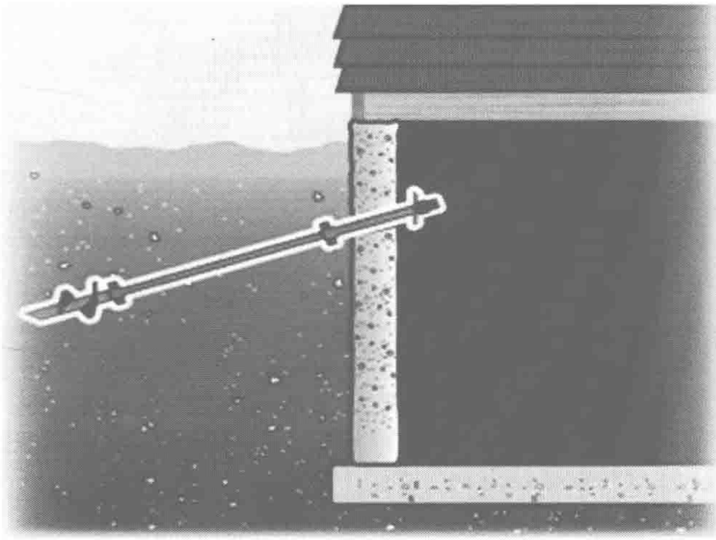

Figure 1.7 A single helical anchor supporting a retaining wall.

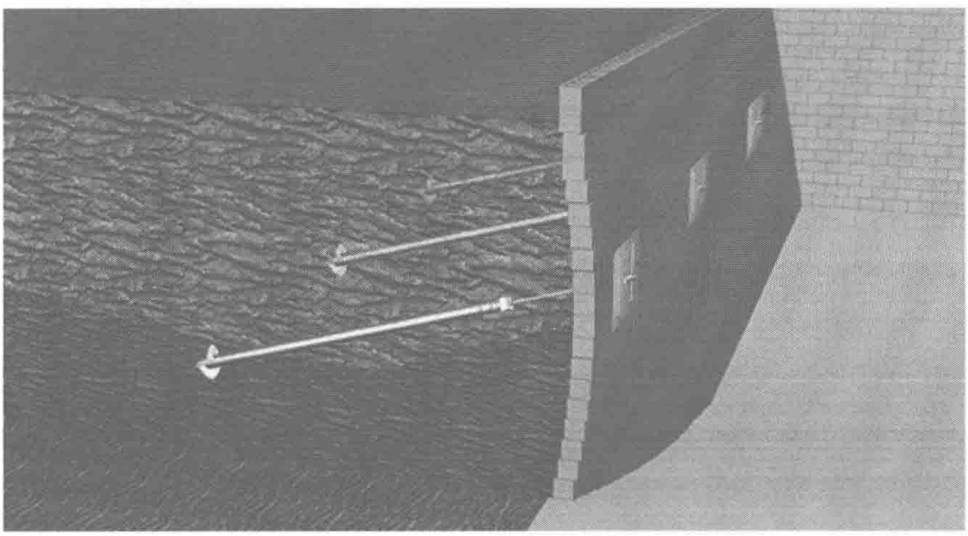

Figure 1.8 Multiple helical anchors supporting a retaining wall.

on a helical anchor shaft is not influenced by the helix above or below it. The capacity of a helical anchor under compression or tension is directly dependent on the bearing capacity of the helical plates against the soil in which it is located, hence the capacity of helical anchors increases as the area of the helical plates and the ground friction angle increases. This system helps the grout gain capacity and obviates disposal of soils, which becomes more important in contaminated soils. Figs. 1.9 and 1.10 show images of helical anchors. The installation of helical anchors is shown in Fig. 1.6.

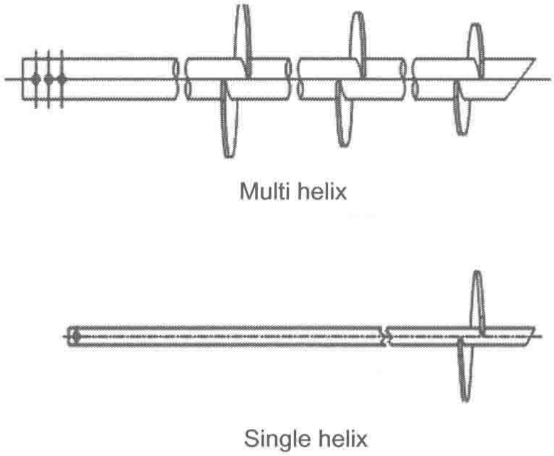

Figure 1.9 Types of helical anchors.

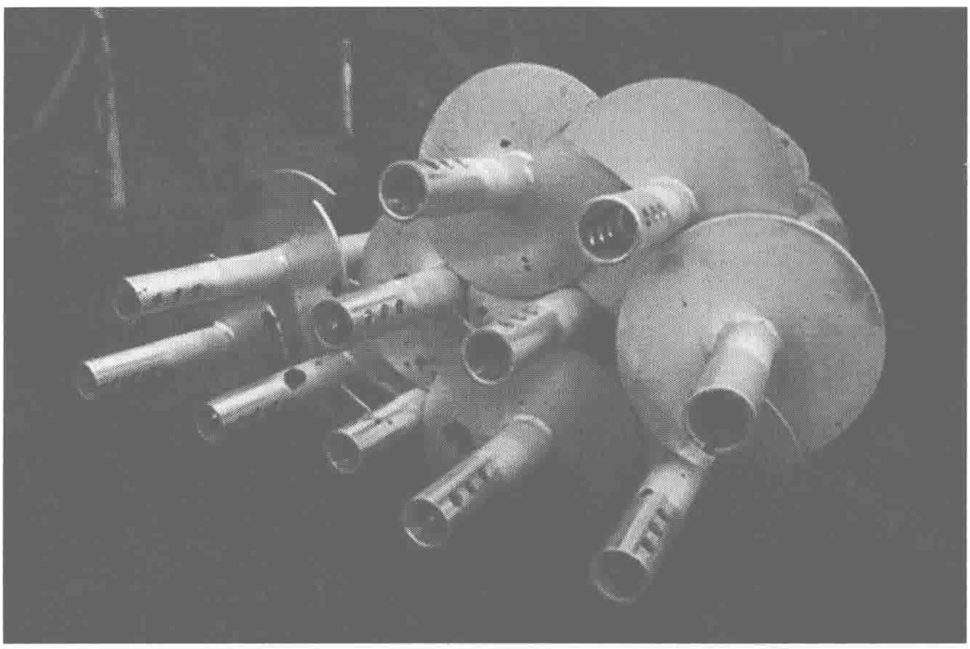

Figure 1.10 Multiple helical anchors.

1.4 ANCHOR PLATES

For transmission towers, masts, and structures subjected to buoyancy effects, anchor plates are the most useful of soil anchors. Anchor plates consist of light structural elements that are used to resist against uplift forces. The way anchor plates are installed depends on the direction of the load applied. For instance, in resistance against vertical uplifting

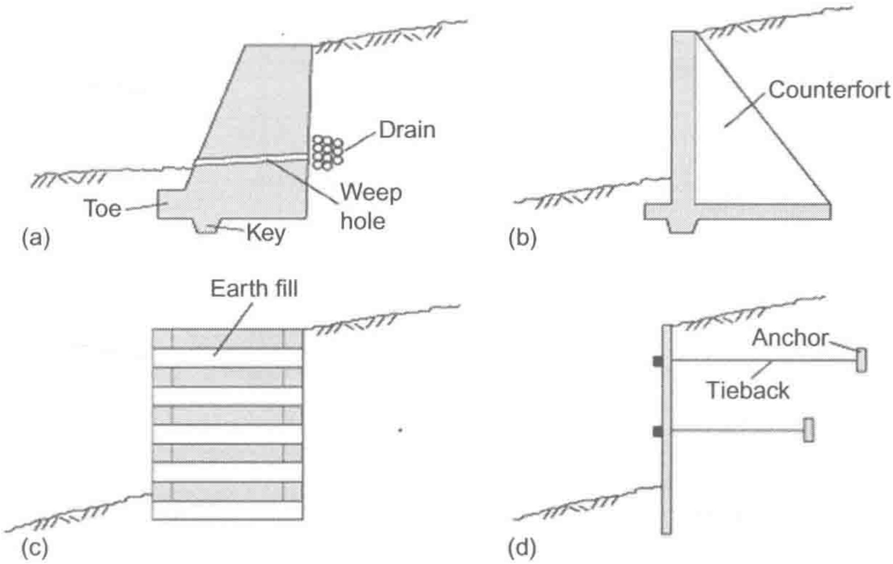

Figure 1.11 Vertical anchor plates used in construction.

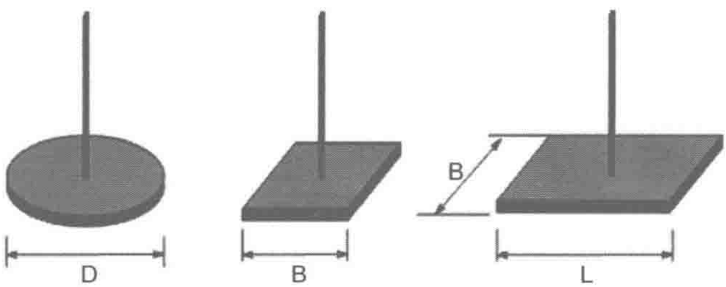

Figure 1.12 Different shapes of anchor plates.

loads, horizontal anchor plates are embedded; whereas vertical anchor plates are used to resist horizontal uplifting loads. Inclined axial loads, on the other hand, are used to resist axial pullout loads. For installation, the soil should be excavated to the required depth and then backfilled with the ground soil after placing the anchor plate (Fig. 1.11). Anchor plates are installed in excavated trenches as support for retaining structures. The shape of the anchor plate, such as square, strip or circular, is determined based on the bearing capacity of the anchor plate and the inflicted tension against the soil in which it is located (Fig. 1.12). These anchor plates are attached to tie rods that may either be driven or placed through augured holes (Fig. 1.13).