In this lecture we will learn about the basics of pile foundation design and the advantages and disadvantages of the main types of pile.

Introduction

In previous lectures we have learned about shallow foundations (pads, strips) and retaining walls. Piles are relevant to both of these lectures because they can be either a deep foundation (where shallow foundations are unsuitable) or, if installed in a line, can be an embedded cantilever retaining wall.

In this lecture, we will study piles only as deep foundations. A pile is a column-shaped structure in the ground. Its length is usually significantly larger than its width or diameter.

Where are pile foundations required?

There are several reasons why pile foundations are needed instead of shallow foundations. They include the following:

- To take foundation loads down to stronger or stiffer soil layers than those at the surface.
- To support horizontal forces, such as from bridge supports due to braking vehicles.
- To increase the stability of tall buildings.
- To avoid damage to foundations caused by erosion of soil in fast flowing water.
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Figure 1: Situations where pile foundations are more practical

Pile design

Figure 2 shows the two mechanisms by which piled foundations are supported by the soil.

i) shaft friction between the pile and the soil which depends on the strength of the soil and the pile/soil friction angle and, in drained analyses, also depends on the effective stress in the soil.

ii) end bearing which is calculated using modified bearing capacity formulas.

In pile designs it is also important to check that the pile material (usually reinforced concrete or steel) is not over-stressed.

Pile settlements need to be checked in addition to the ultimate limit state load. However, pile settlements are difficult to predict. Therefore, a factor of safety of between 2 and 3 is used on the ultimate pile load and pile load tests are normally carried out on each site to check that the settlements of piles are acceptable.

Negative shaft friction

Shaft friction, as shown in Figure 2, will only support the pile (i.e. act upwards) if the pile is moving down relative to the soil. There are some situations, however, where the soil around the pile moves down relative to the pile. In these situations the shaft friction is called negative because instead of supporting the pile it helps to push it into the ground.

The most common situation where this occurs is when a thick layer of fill is placed on a clay before construction starts on a site. The weight of the fill causes the clay to settle over several years. The clay may settle 20mm for example near the top of the clay layer and the pile settle only 10mm. This means the clay is moving down relative to the pile and the shaft friction between the pile and the clay is negative.

Figure 3: Example of a situation where negative shaft friction occurs
Pile types

There are many different types of pile and installation methods, each suitable for different situations.

The two general methods of installation are driven or bored. Driven piles are pushed, hit or vibrated into the ground. A driven pile is made in a factory before installation. In bored piling, the hole for a pile is bored (excavated) first and then the pile is formed in the hole.

The two most common pile materials are steel (always driven into the ground) and reinforced concrete (either pre-cast and driven into the ground or cast-in-place to form a bored pile).

Below are described the characteristics, advantages and disadvantages of driven and bored pile types. There are, of course, many variations of these types.

Driven piles

The piles are made in a factory to specified sizes and brought to site. The piles are pushed or hit into the ground. Piles can be made from reinforced concrete with pile lengths up to 27m and pile loads up to 1000 kN. The piles can also be made from steel tubes or steel ‘H’ sections. Steel piles can be up to 36m long with loads up to about 1700 kN.

Advantages:
- Driven to a designed resistance (every pile is load tested by measuring how difficult it is to drive it into the ground).
- Pile material can be checked before installation.
- Installing piles into groundwater is not a problem.
- Pile can be left above ground level (e.g. when installing piles through water for marine structures).

Disadvantages:
- Difficult to change lengths of concrete piles.
- Pile may be damaged during driving.
- Pile driving is noisy and causes ground vibrations.
- Large diameter piles cannot be driven.
- Steel piles are expensive and will corrode.

Bored piles

A hole in the ground is bored (excavated) with a rotary auger (drill). Often the hole will need to be supported with a temporary steel casing or bentonite clay to stop the sides of the hole from collapsing. The concrete is then poured into the hole to form the pile. Reinforcement for the pile can be installed before casting the concrete or immediately afterwards. Pile lengths of up to 45m can be installed and loads of up to 10,000 kN are not unusual.

Advantages:
- Easy to vary pile sizes and lengths.
- Very large diameters and lengths to support very large loads are possible.
- Soil excavated for the pile can be inspected to check it is the same as assumed in design.
- Additional reinforcement for driving is not needed.
- Pile installation is quiet compared with pile driving.

Disadvantages:
- The pile material cannot be inspected and necking is possible.
- Installing piles in groundwater can be difficult as flowing water can damage the fresh concrete.