



ACEG434 FOUNDATION ENGINEERING

Parameters for foundation design

Objective

In this lecture we will learn about all the soil parameters we need to carry out a foundation design. We will also learn about assessing the risk of foundation movements from the swelling and shrinkage of clays.

Introduction

Any geotechnical design, including foundation design, goes through stages of a) site investigation, b) interpretation (or soil parameters determination) and c) design.

We have already learned about stage a) "site investigation" and a little of b) "interpretation" in previous lectures. We will now learn a little more about interpretation and the determination of all the soil parameters we need for foundation design.

When designing foundations on cohesive soils (silts and clays) we also need to determine parameters to assess the risk of swelling and shrinkage of the soil. We will learn about this important assessment.

Soil Parameters

Bearing capacity of granular soils (sands and gravels)

We need the soil's shear strength (friction angle) ϕ' ($^\circ$). This is estimated from in-situ tests such as the Standard Penetration Test (SPT) as described in the previous lecture.

We need the bulk weight density γ_{bulk} (kN/m^3) of the soil. This can also be estimated from SPT results, visual descriptions and particle size.

We also need the minimum depth to the water table.

Bearing capacity of cohesive soils (silts and clays)

Usually we only calculate the short-term undrained bearing capacity, but if we have to calculate the long-term drained bearing capacity then we will need the drained shear strength (friction angle) ϕ' ($^\circ$). This is measured using laboratory triaxial tests.

We always calculate the short-term undrained bearing capacity of cohesive soils and for this we need the short-term undrained shear strength c_u (kPa). This can be measured from laboratory shear box and triaxial tests or estimated from in-situ tests as we learned in the previous lecture.

Usually, undrained shear strength c_u (kPa) increases with depth, as shown in Figure 1, so which value do we choose for our bearing capacity calculation? In these cases, we take the average c_u value over a depth equal to $\frac{2}{3}B$.

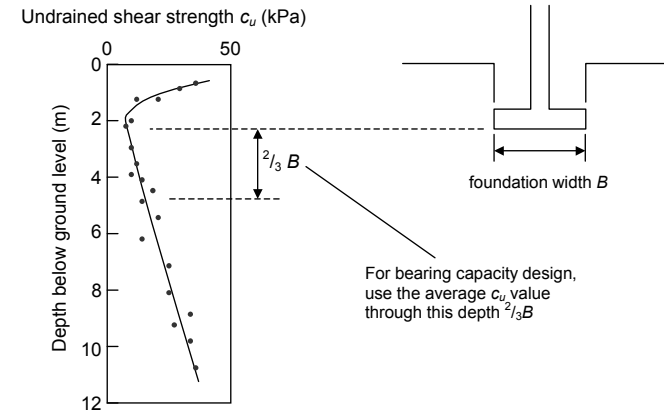


Figure 1: Calculation of average c_u value for bearing capacity calculation

We also need the bulk weight density γ_{bulk} (kN/m^3) of the soil. This can be measured in the laboratory on undisturbed samples, as we did in *Soil Mechanics I*.

For long term drained calculations, we need the minimum depth to the water table.

Settlement on granular soils (sands and gravels)

We need the stiffness E'_0 of the soil. This needs to be measured in-situ and the best method is the plate loading test. But, as you learned in the previous lecture, it is possible to estimate an approximate value of stiffness E'_0 from the SPT and good estimates can also be made from shear wave velocity measurements.

There are also some methods of estimating settlement directly from SPT and other in-situ test results, without first finding a value of stiffness E'_0 . One of these will be described in the settlement lectures later in this subject.

Settlement on cohesive soils (silts and clays)

To calculate settlement on cohesive soils, as you learned in *Soil Mechanics I*, we measure soil stiffness E in the laboratory, either with an oedometer test or triaxial test. As we will learn in the settlement lectures later in this subject, we need to differentiate between immediate settlement and long-term consolidation settlement. The division of these settlements can be estimated from the oedometer settlement values. Alternatively, the stiffness of the soil can be differentiated between the short term undrained stiffness E_u and the long-term drained stiffness E'_0 .

The undrained stiffness E_u can be measured in the laboratory using a triaxial test, although it is often difficult to select a value. A common way to estimate the parameter is from correlations with the undrained shear strength c_u , which is easier to measure. Many correlations have been suggested, with large differences between them. It is better if settlement data already exists for other structures on similar soil, then the correlations can be checked.

For foundations with small settlements:

Low-plasticity clays $E_u/c_u \approx 500$

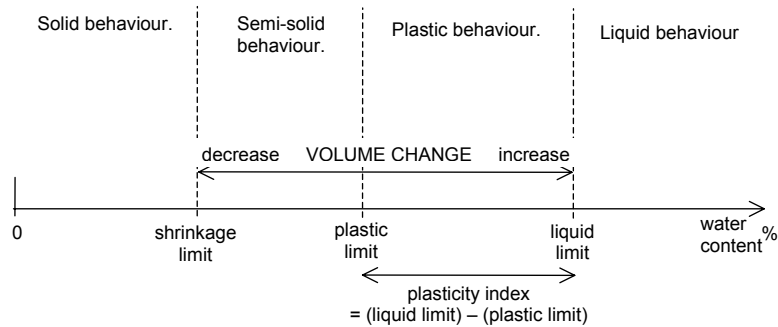
High-plasticity clays $E_u/c_u \approx 250$

The drained stiffness E'_o is measured in the laboratory using an oedometer test or a triaxial test.

Assessment of potential for swelling and shrinkage of clays

As you learned in *Geology* and *Soil Mechanics I*, clays swell (increase in volume) when water is added and shrink (decrease in volume) when water is removed. Even after carrying out a correct foundation design for settlement and bearing capacity, these volume changes can cause movements of foundations large enough to damage the buildings they support.

Most swelling and shrinkage of clays happens when the clay is *plastic*, i.e. the water content of the clay is between its liquid limit and plastic limit:



Therefore, there is a high risk of damage from swelling and shrinkage of clays with high plasticity, or a high plasticity index. These clays are called *expansive clays*. Generally, an expansive clay has a plastic limit above 15% and a liquid limit above 40% and if the plasticity index exceeds 35%, they will have a high potential to swell and shrink. Many of the clays in Cyprus are expansive clays and there are many examples of their damage to buildings.

However, an expansive clay will only swell and shrink if the water content changes through the range between the plastic and liquid limits. If the water content of an expansive clay changes but is always below the plastic limit, this is not a problem.

Therefore, to assess the potential for swelling and shrinkage below a foundation there are two sets of measurements to take:

1. Determine the plastic limit and liquid limit of the clay under the proposed foundation to check whether it is an *expansive clay* and to assess its swelling potential.
2. Take samples of the clay at different depths under the proposed foundation at different times of the year and measure their water content. This will tell you the seasonal variation of water content and to what depth these changes occur (the *active zone* see Figure 2). If part or all of the seasonal variation in water content occurs above the plastic limit, then some changes to the foundation design will be required.

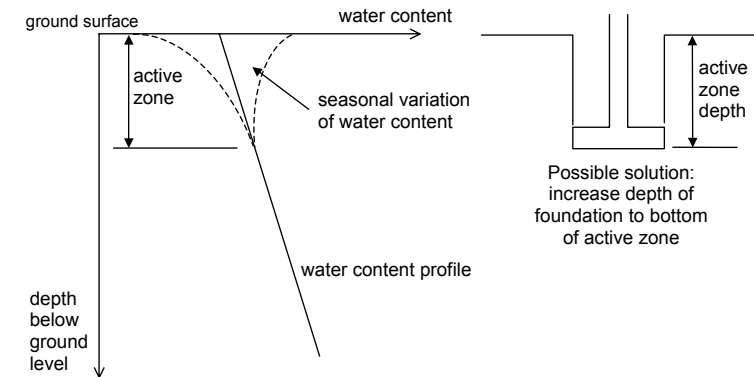


Figure 2: Seasonal variation of water content and active zone

Possible solutions to building foundations on expansive soils:

1. Increase the depth of the foundation to the bottom of the active zone so that swelling and shrinkage of the clay will not affect the foundation.
2. If there is a shallow depth of expansive clay overlying non-expansive soil, it can be removed and replaced with a granular fill material.
3. The strength of the structure can be improved so that it will not be damaged by movement of the foundations.
4. Improve the expansive clay with methods such as compaction or soil/lime or soil/cement mixing.