Properties of granular and cohesive soils

Objective

In this lecture we will learn about some more properties of soils that are used to predict their engineering behaviour.

Introduction

In the previous lecture we learned about the basic phase relationships of soils and these are measured in the same way for all soils. But the engineering behaviour of soils varies a lot between different soil types. Clays behave very differently to gravels.

We will learn about the first stage of measuring the engineering properties of granular soils (gravels, sands and silts) by the size of the soil particles. Then we will learn about the first stage of measuring the engineering properties of cohesive soils (silt and clays), soils where the particles sizes are too small to be measured easily.

Soil particle size

Gravel particles: 2mm to 60mm diameter. Can be seen easily with the eye.

Sand particles: 0.06mm to 2mm diameter. Can be seen with the eye.

Silt particles: 0.002mm to 0.06mm diameter. They can only be seen with a microscope or a hand lens (x10).

Clay particles: less than 0.002mm wide, very thin plates rather than round particles. They can only be seen with an electron microscope.

The surface of soil particles carry a small electrical charge, depending on the soil mineral. These charges cause forces between the soil particles. The magnitude of the force depends on the area of contact between soil particles. The relative importance of the force depends on the weight of each soil particles.

Therefore, in silts, sands and gravels where the soil particles are approximately round and the contact areas are small, the particle forces are very small.

In clays, where the particles are very thin plates, the contact areas are large and the particle weights small, the particle surface forces are more significant. This causes clays to have a little cohesion where the particles stick together.

Particle size distribution

Many engineering properties of soils can be estimated from the sizes of their particles. You will learn about these engineering properties later in the course but they include strength, suitability as compacted fill and the ease with which water can flow through the soil.

Only some soils contain particles which are all about the same size. Most soils contain a number of different sized particles and it is the relative amounts of each size that affect the engineering behaviour of the soil.

The relative amounts of particle sizes in a soil are shown with a graph like the one in Figure 1. The particle sizes are shown along the horizontal axis (on a logarithmic scale) and the percentages of each particle size by weight found in the soil are shown on the vertical axis. This is a cumulative percentage, which means that the percentages are added up from the smallest size up to the biggest giving a particle size distribution curve. Any point on the curve shows the percentage of the particles in the soil which are smaller than any particular size.

A smooth curve shows that a soil has a good amount of different particle sizes and is called well-graded. A curve which is very steep or near-vertical indicates that most of the particles in a soil are the same size and is described as uniform.

The particle sizes between fine sand and coarse gravel can be measured in the laboratory with a series of sieves. Particle sizes smaller than fine sand have to be measured with a different technique – sedimentation – which involves measuring the velocity of particles falling through water. Sedimentation tests take time and are expensive and usually the Atterberg limit test on silts and clays is sufficient to estimate the particle sizes smaller than fine sand.
Consistency of clays

It is difficult to measure the particle sizes of silt and clay soils, so we use a different method to classify them. A lot of information can be obtained by measuring the water content at which a soil changes its behaviour, or consistency.

When a clay can be moulded in the hand without cracking and without running like a liquid, it is said to be plastic. If the water content of a clay is too low, the clay will be dry and hard. If the water content of a clay is too high, the clay will behave like a thick liquid.

These water content values at the lower and upper limits of plastic behaviour can be determined in the laboratory and are called the Atterberg limits:

Plastic limit: the water content below which the clay is no longer plastic and appears dry and breaks up.

Liquid limit: the water content above which the clay behaves like a liquid.

At water contents between these two limits, a clay will be plastic.

Plasticity Index is the range of water content over which the clay behaves in a plastic way.

As you learned in Geology, clays increase in volume (swell) with increasing water content and decrease in volume (shrink) with decreasing water content. Clays change volume without cracking only when plastic. When the water content falls below the plastic limit, the clay shrinks even more until the water content reaches the shrinkage limit, but the clay shrinks by cracking.

This swelling and shrinkage moves the foundation of buildings and can cause serious damage. Volume change between the plastic limit and the shrinkage limit is more horizontal, but volume change while the clay is plastic is horizontal and vertical. Therefore, the bigger the Plasticity Index of a clay, the bigger the movement of a foundation and the bigger the risk of building damage.

When building on a clay/silt soil, it is VERY important to determine the Atterberg Limits and plasticity index of the soil before the foundations are designed, so that damage due to shrinkage and swelling can be avoided.

The liquid limit, plastic limit and plasticity index are very different for different silts and clays. The values are affected by the mineralogy and clay content of the soil. Therefore, laboratory tests for the Atterberg limits can also be used to estimate the composition of the soil.

A clay with a high silt content, for example, would have a low plasticity index and perhaps also a high liquid limit.