

UNCONFINED COMPRESSION TEST

PURPOSE

The purpose of this laboratory is to determine the unconfined compressive strength of a cohesive soil sample. We will measure this with the unconfined compression test, which is an unconsolidated undrained (UU or Q-type) test where the lateral confining pressure is equal to zero (atmospheric pressure).

INTRODUCTION

The unconfined compression test is by far the most popular method of soil shear testing because it is one of the fastest and cheapest methods of measuring shear strength. The method is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The unconfined compression test is inappropriate for dry sands or crumbly clays because the materials would fall apart without some land of lateral confinement.

To perform an unconfined compression test, the sample is extruded from the sampling tube. A cylindrical sample of soil is trimmed such that the ends are reasonably smooth and the length-to-diameter ratio is on the order of two. The soil sample is placed in a loading frame on a metal plate; by turning a crank, the operator raises the level of the bottom plate. The top of the soil sample is restrained by the top plate, which is attached to a calibrated proving ring. As the bottom plate is raised, an axial load is applied to the sample. The operator turns the crank at a specified rate so that there is constant strain rate. The load is gradually increased to shear the sample, and readings are taken periodically of the force applied to the sample and the resulting deformation. The loading is continued until the soil develops an obvious shearing plane or the deformations become excessive. The measured data are used to determine the strength of the soil specimen and the stress-strain characteristics. Finally, the sample is oven dried to determine its water content. The maximum load per unit area is defined as the unconfined compressive strength, q_u .

In the unconfined compression test, we assume that no pore water is lost from the sample during set-up or during the shearing process. A saturated sample will thus remain saturated during the test with no change in the sample volume, water content, or void ratio. More significantly, the sample is held together by an effective confining stress that results from negative pore water pressures (generated by menisci forming between particles on the sample surface). Pore pressures are not measured in an unconfined compression test; consequently, the effective stress is unknown. Hence, the undrained shear strength measured in an unconfined test is expressed in terms of the total stress.

APPARATUS

The loading frame consists of two metal plates. The top plate is stationary and is attached to the load-measuring device. The bottom plate is raised and lowered by means of a crank on the front of the loading frame. After the soil sample has been placed between the plates, the bottom plate is gradually raised; the resistance provided by the stationary top plate

applies an axial force to the sample. Although the loading frames in our laboratory are hand operated, electric motor-driven and hydraulic load frames are common. Loads are measured with a calibrated proving ring or an electronic load cell. Vertical deformations are measured with a dial gauge; the dial gauge is attached to the top plate and measures the relative movement between the top and bottom plates. We will be performing a strain-controlled test, in which the load is applied at a constant rate of strain or deformation

PROCEDURE

1. The first step in the procedure is to examine the loading frame. Turn the crank and learn how to read the load and deformation dial gauges. Determine the calibration constant for the proving ring and the units of the deformation dial gauge.
2. We will be shearing the samples at a strain rate of 1% per minute. From the length of your soil sample, determine the deformation at 1% strain. Depending on the units of the vertical deformation dial gauge (usually 0.001 inches or 0.0001 inches), determine the number of dial divisions per 1 strain- Practice turning the crank at his number of dial divisions/minute. It is important that the soil sample not be sheared faster than this specified rate
3. Measure the initial height and diameter of the soil sample with calipers. It is unlikely that the sample will be a perfect right cylinder. Therefore, it will be necessary to find the average height and diameter by taking several measurements in different places along the soil sample. The measurements should be taken by more than one member of a lab team to be sure that the calipers are read correctly. If you have any questions about how to take measurements with calipers, ask the laboratory instructor for instruction.
4. Record the weight of the soil sample and determine the total (moist) unit weight.
5. Place the soil sample in the loading frame, seat the proving ring and zero the dials.
6. During this lab you will record the load applied at specified strain values. It is recommended that readings be taken at strains of 0,0.1,0.2, 0.5, 1,2,3,4,5,6,8, 10, 12 14, 16, 18 and 20 percent. You should prerecord the vertical deformation dial readings at these strain values. With the measured initial height of sample (H_0), the desired percent strain (ϵ) and the initial dial reading (S_0), calculate the dial readings (S) as follows:

$$S = S_0 + \left(\frac{\epsilon}{100}\right)H_0$$

7. Readings of force (F) are taken from the proving ring dial gauge and the stress applied to the ends of the sample (σ_1 , or major principal stress) is computed as follows:

$$\sigma_1 = \frac{F}{A}$$

where A is the cross-sectional area of the sample. Because the soil sample height decreases during shear and the volume of the sample remains constant, the cross sectional area must increase. For a saturated soil that undergoes no volume change during shear (no flow of water into or out of the sample), the equivalent or average area (A) at any strain (ϵ) is computed from the initial area (A_c) and the assumption that volume is conserved:

$$A = \frac{A_0}{1 - \epsilon}$$

8. Shear the sample at a strain rate of 1% per minute. Typically, the sample fails in one of two ways. In stiffer clays, a distinct failure plane forms. For this type of failure, it is likely that the point of failure will be indicated by the measurement of a peak and then a decrease in load. If this is the case, continue to take four or five readings past the point of failure. (Caution: before you stop shearing the sample, be sure that the sample has failed.) A "barreling" failure is more typical for softer clays. In this type of failure, a distinct failure plane doesn't form, rather the sample bulges in the middle

The unconfined compressive strength (q_u) is the maximum value σ_1 , which may or may not coincide with the maximum force measurement (depending on the area correction). It is also equal to the diameter of Mohr's circle as indicated in Fig. 1. The undrained shear strength (s_u) is typically taken as the maximum shear stress, or:

$$S_u = \frac{1}{2}q_u$$

If σ_1 continues to increase up until 20 vertical strain, i.e. does not reach a maximum and then decrease, the sample has failed by "barreling". In this case, q_u is defined as the value of σ_1 measured at 20% strain.

9. When your lab team has completed the experiment, dismantle the loading frame and measure the water content of the soil sample. It is recommended that you reduce the data for this test during the lab period.

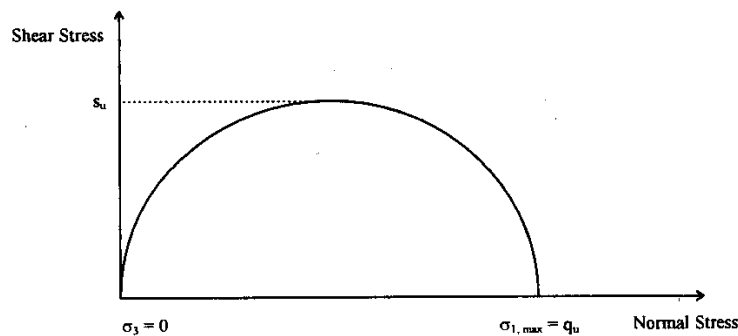


Figure 1: Mohr's Circle for the Unconfined Compression Test

SOURCES OF ERROR IN THE UNCONFINED COMPRESSION TEST

There are a number of sources of error in the unconfined compression test. One of the largest sources is the use of an unrepresentative sample of soil. The soil may be unrepresentative because it is not the same as, or perhaps even similar to, the bulk of the soil found in the ground. The sample can also be unrepresentative if it has been disturbed or changed from its original state. A common cause for disturbance is the soil sampling process. Disturbance usually has the effect of lowering the strength of the soil and reducing the slope of the stress-strain curve, as shown in Figure 2

If the sample is too short there will be significant end effects. End effects are caused by the top and bottom loading plates that grip the sample. They can increase the strength of a soil sample by preventing the formation of the weakest failure plane. If the sample is too long, we find that it tends to buckle. A length-to-width ratio of two to three is recommended to

avoid this problem. The effect of length-to-width ratio on the unconfined compressive strength is shown in Figure 3.

Another source of error is that the soil is not confined during shear but will be confined in the field if the soil is located at a depth of a few feet or more. The problem is most severe with fissured soils (soils that contain cracks). In the ground, the cracks are held closed by the confining pressure due to the weight of soil above it. The soil is much stronger in this state than it is with no confining pressure in an unconfined compression test.

For example, soil tested from the South Texas Nuclear Power Plant project indicated shear strengths on the order of 1,500 psf when tested in unconfined compression. Other samples were tested in a triaxial apparatus (where confinement similar to that in the ground is applied) and the strengths averaged 4,500 psf. Thus, for the fissured soils at this site, the unconfined compression test led to a significant underestimation of the strength of the soil. In fact, because the unconfined compression test does not provide confinement for the soil, and because of the effects of sampling disturbance, strengths measured in the unconfined compression test are usually a lower bound of the actual strength. However, use of an underestimated shear strength in geotechnical analyses is almost always conservative and is not necessarily bad, so long as the strength used is not too much lower than the actual field strength. For certain intact (not fissured) clays that are not susceptible to much sampling disturbance, the unconfined compression test is actually an excellent test.

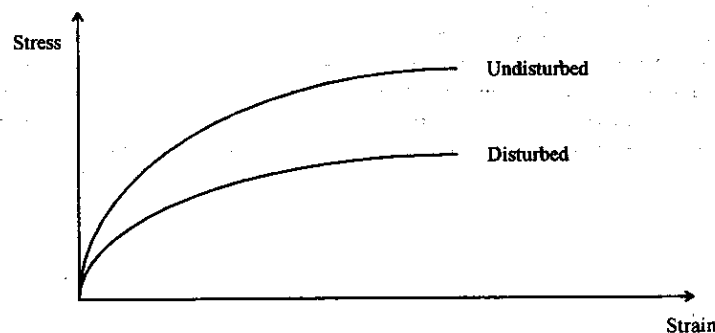


Figure 2: Effects of Disturbance on Stress-Strain Behavior

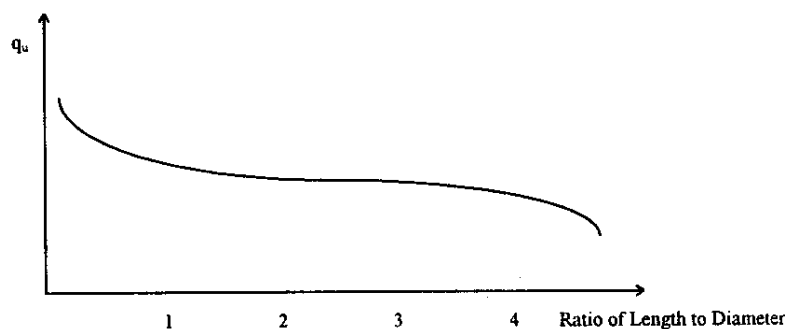


Figure 3: Effect of Length-to-Diameter Ratio on Unconfined Compressive Strength of Soil