SSC 107 - LABORATORY EXERCISE 2

Determination of Soil-Water Characteristic Curves Using the Tempe Cell

Introduction

At a given degree of wetness, a soil (or any other porous medium, say a sponge) exhibits a certain suction. The dryer the medium, the more forceful the suction. Wetness is expressed either as S (degree of saturation, or volume of H_2O per volume of pore space), or as θ_v, (volume H_2O per volume bulk soil). The suction is usually expressed as a tension (i.e., in negative pressure units) or as the water-column equivalent of that negative pressure, also known as "matric head"(negative cm H_2O). The relationship between soil water content and tension is called the soil-water characteristic curve. It is of fundamental importance for many processes occurring in the soil. Pore size distribution has important influence on this relationship. Even a single pore can subject a liquid to a tension - remember the example of capillary rise (Fig 2-1).

The smaller the pore diameter, the smaller the radius of curvature of the air-water interface, i.e., the more curved the interface (or meniscus). As a soil sample dries, the biggest pores empty first, then smaller and then still smaller pores. Because smaller pores hold the water more strongly, soil water tension rises as the sample gets drier.

You can think of the meniscus as representing the pressure jump from the air phase to the water phase; the difference between air pressure and soil water pressure is often called capillary pressure:

$$p_{capillary} = p_{air} - p_{water} \qquad \text{[Eqn. 1]}$$

This pressure difference is characteristic for the soil water content of a given sample.

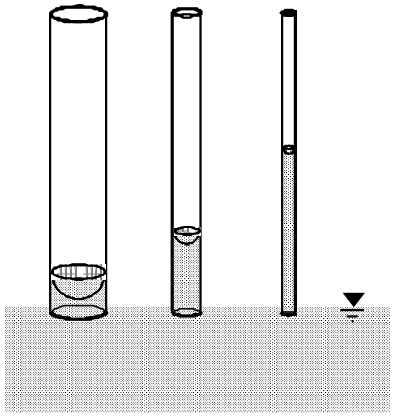

Figure 2-1. Capillary rise in tubes

Let's say a sample is at 50% volumetric water content. Its air phase is at atmospheric pressure (taken as 0 bar) and its water phase at a tension of -0.1 bar (= -100 cm matric head, = -9,800 Pa). If the water phase of this sample were to be brought to atmospheric pressure (e.g., by exposing its bottom to a open water reservoir through a ceramic plate), it would take exactly +0.1 bar air pressure inside the sample to keep the water content at 50%. The pressure difference (air - water) is the same in both cases: 0.1 bar!

The Tempe cell makes use of this fact. Rather than applying a suction to the water phase and keeping the soil air at atmospheric pressure as in the hanging water column method, the soil water is kept at atmospheric pressure using an open burette and excess air pressure is applied to the soil air phase from the top (Fig. 2-2). The ceramic plate at the bottom is penetrable to water but not to air-otherwise the excess air pressure inside the cell could not be maintained.

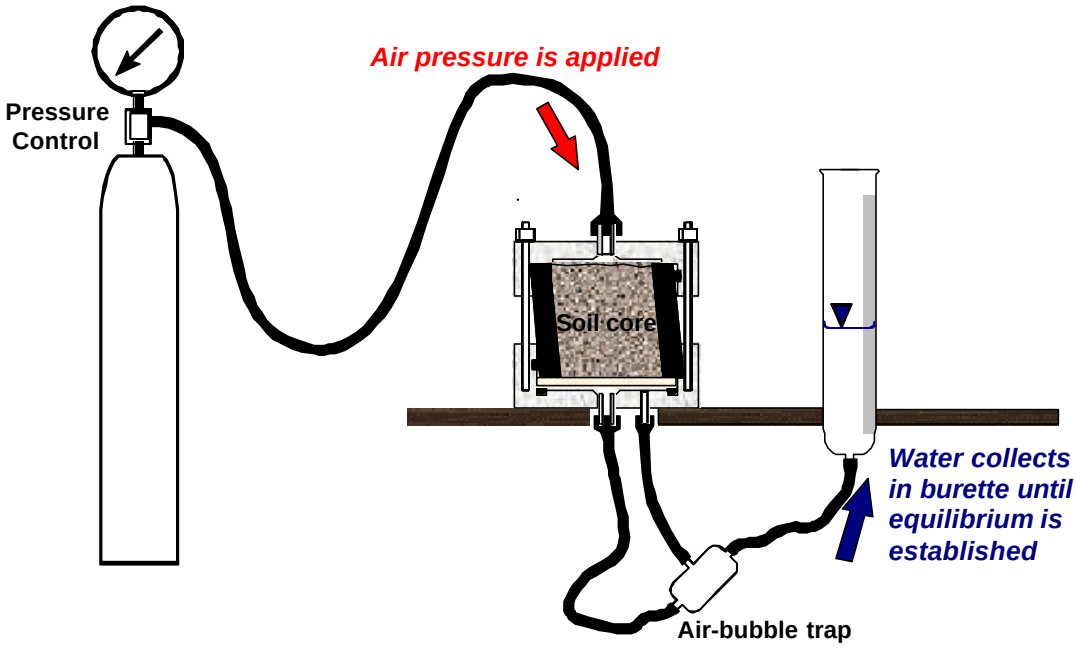

Fig. 2-2. Components of the Tempe cell method

Starting at saturation, some of the soil water will flow out into the burette once the first excess pressure step is applied. After a certain amount of time (hrs..?..weeks), equilibrium will be attained. The total outflow volume into the burrette will be measured and can be used to calculate the water content of the sample that corresponds to the applied capillary pressure. Each pressure step thus produces one point of the soil-water characteristic curve.

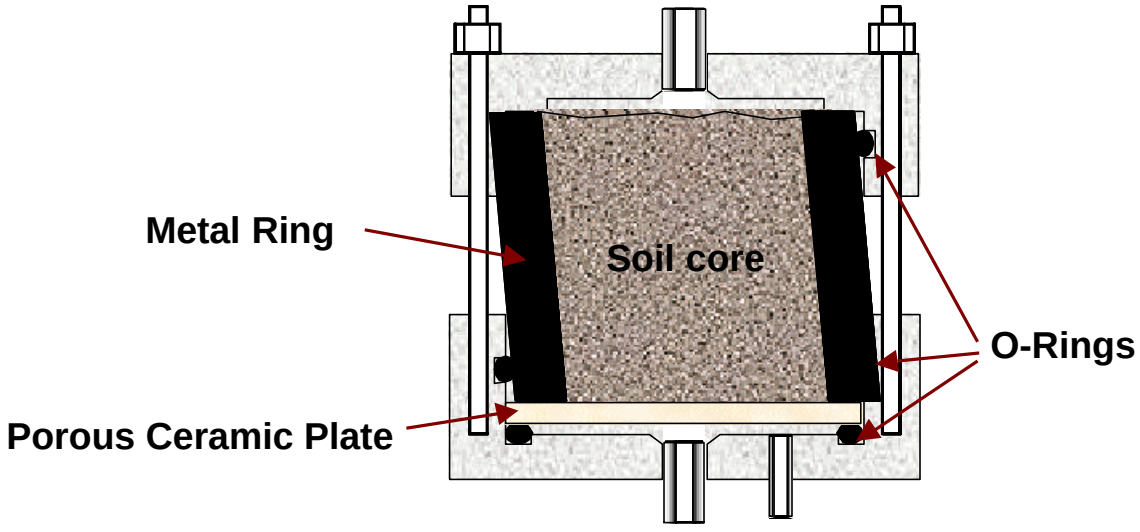

Fig. 2-3. Vertical cross section of the cell

Procedure

1. Saturate the ceramic plate for at least 1 day.

2. Install O-rings and ceramic plate in bottom unit of cell (see Fig.2). Careful: don't chip the plate with the metal rods! Use Vaseline to lubricate the O-rings.

3. Attach Tygon tubing to both bottom outlets, the bubble trap, and the burette.

4. Fill the system with water through the burette. Air should escape around the ceramic plate.

5. Pack cores with soil to a given bulk density. **It is important that soil surface is flush with the top of the ring**.

6. Place the core on the ceramic plate. Again, careful: don't hit the plate with the metal ring! Make sure the O-ring sealing the sample holder stays in place.

7. Install and tighten top unit (don't forget the O-ring). No excessive force is necessary - remember, the plates crack easily.

8. If there was some air entrapped between plate and sample, press the Tygon tubing attached to the larger bottom outlet with your hand to pump out the air bubbles into the trap - from there they will find their way up through the burette.

9. Raise the water level in the burette to a point above the sample to allow the soil to saturate through the ceramic plate.

10. Move burette down so that water level is at one-half the height of the sample. After each reading, lower the burette to adjust the water level at one-half the height of the sample. Record the outflow once a day until no change is observed within a specified period.

11. The soil sample is now at equilibrium at zero capillary pressure- both the air and the water phase are at atmospheric pressure. Connect air tubing to the top unit, record the water level reading in the burette and start first pressure step.

12. Record the outflow **once a day** until no change is observed within a specified period. After each reading, lower the burette to adjust the water level to the midpoint of the sample. (Repeat for all pressure steps.)

13. At the end of the experiment, dry the soil in the oven order to determine the mass of water left in the sample.

14. Calculate the volume of the soil core.

15. Determine the volumetric water content of the soil core at the last pressure step. From the volume of water drained between the last and the previous pressure step, the volumetric water content at the previous step can be calculated. Repeat this for all pressure steps including the initial zero (i.e., atmospheric) pressure. Plot water content versus capillary pressure head - this is your soil water characteristic curve.

16. Calculate the bulk density from the oven-dry soil mass and the core volume.

Lab Report Point Distribution

Abstract: 0.75
Material and Methods: 0.5
Results: 2.75
Discussion: 4.75
Conclusion: 0.5
Overall Composition: 0.75
Total: 10